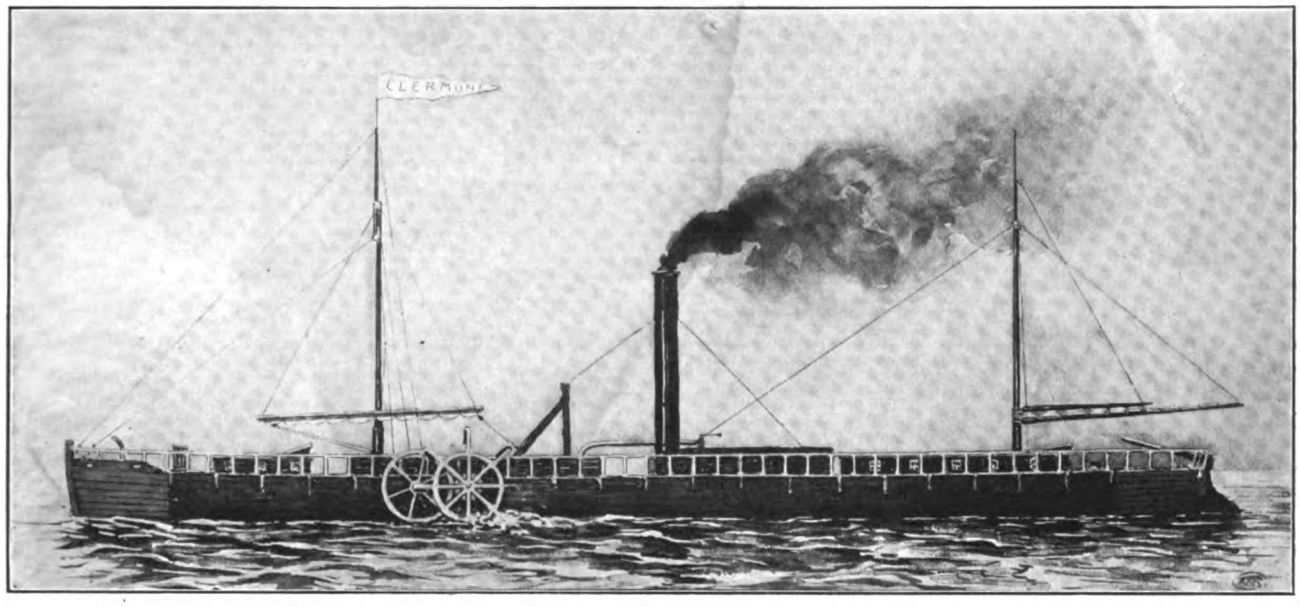
International Marine Engineering

SEPTEMBER, 1909.

THE CLERMONT.

The first practical steamboat to engage successfully in commercial navigation was the *Clermont,* built by Robert Fulton in 1807, at Charles Brown's shipyard, near Corlear's Hook, New York, and placed in service on the Hudson River between New York and Albany. She was 150 feet long, 13 feet wide with 7 feet depth of hold and a draft of 2 feet. The hull was flat-bottomed and wall-sided, slightly wider at the deck than on the bottom, with a wedge-shaped bow and stern cut to an angle of 60 degrees. The parallel middle body extended for almost the entire length of the boat. Two masts and two cabins were fitted, one forward and one aft. She was steered by a tiller at the stern, and two lee-boards were fitted to prevent drifting sideways. Propulsion was by means of side paddle-wheels, placed well forward and driven by a single-cylinder, vertical, condensing, side lever type engine, supplied with steam at a pressure of 2 or 3 pounds per square inch by a copper boiler. The machinery was built in England, the engine by Boulton & Watt and the boiler by Cave & Son.



FULTON'S CLERMONT, THE FIRST PRACTICAL STEAMBOAT TO ENGAGE SUCCESSFULLY IN COMMERCIAL NAVIGATION.

In connection with the Hudson-Fulton celebration to be held in New York this month a reproduction of this historic little vessel has been built as nearly like the original as would be allowed by the steamboat inspectors, and through the courtesy of the Hudson-Fulton Celebration Commission we are able to publish complete details of this replica. The principal dimensions of the boat, which differ from the original only in the matter of the beam, are as follows:

Length over all	150 feet.
Length at upper deck	149 feet.
Breadth at upper deck	17 feet 11 inches.
Breadth at bottom	16 feet.
Depth of hold	7 feet.

The stem is both sided and molded 8 inches, the stern post is sided 8 inches and molded 12 inches, and the deadwood is sided 8 inches and molded to suit. The floors are sided 4 inches, molded 8 inches and are spaced 24 inches center to center. They are single throughout the boat, with the exception of the machinery space, where they are double. The frames are sided 4 inches and molded 7 inches at the floors and 4 inches at the deck, and are spaced the same as the floors. The center keelson is 10 inches by 10 inches, and the engine, boiler and bilge keelsons 8 by 10 inches. The deck beams are molded 8 inches at the center, 5 inches at the ends, sided 8 inches and spaced 3 feet center to center. The main beams are fastened with hackmatack knees. The bottom planking is 2 by 4 inches, the three bilge strakes 10 by 2 inches, the sheer strakes 10 by 3 inches, the sheer stringer is 12 by 2 inches, and the wearing piece 8 by 3 inches. The deck planking is 4 by 2 inches.

The machinery of the *Clermont* is located amidships, and is entirely uncovered. The paddle-wheels are placed well forward; aft of these is the engine and aft of this again the boiler. The paddle-wheels are 15 feet in diameter, each having eight paddles or buckets 4 feet long and 2 feet wide. Forward of the paddle shaft and connected to it through two to one gears is a jack-shaft, on which are mounted two large fly-wheels, arranged outside the hull. These fly-wheels have cast iron rims, 4 inches by 4 inches, and are keyed to the shaft.

The engine is of the single-cylinder, condensing, side-lever type, designed for a working pressure of 20 pounds per square inch. The cylinder is mounted on a cylindrical condenser, which is connected to the air pump by a channel-way of cast iron, which forms the bedplate of the engine. One boiler-feed

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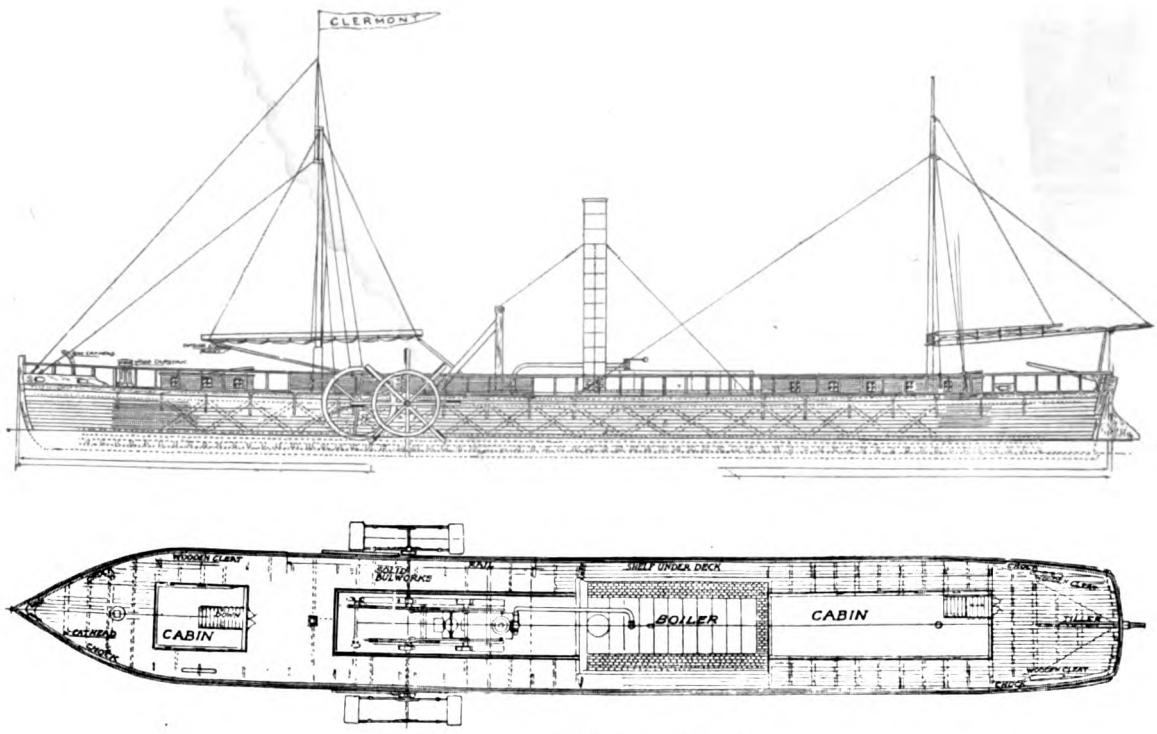
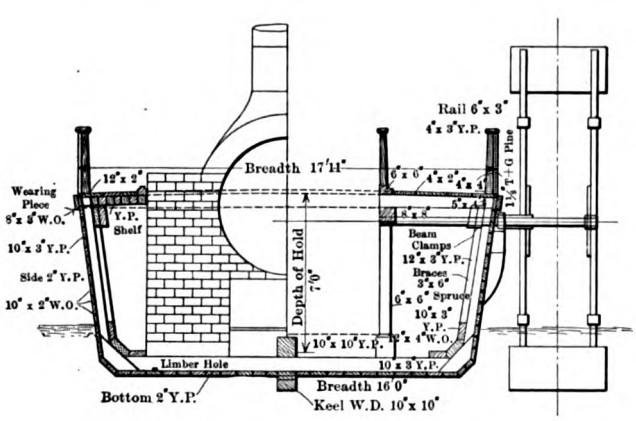
pump is supplied, which has a capacity of 180 cubic inches, and is worked by the air pump cross-head. It has a brass plunger and valve. The bilge pump has a capacity of about 300 cubic inches. The side levers of the main engine are of cast iron



GENERAL ARRANGEMENT OF THE CLERMONT.

on a wrought iron center shaft. Each connecting rod is forked and fitted with wrought pins. Counter weights are provided to balance the weight of the piston, piston rod, crank, side links, air pump gear, etc.

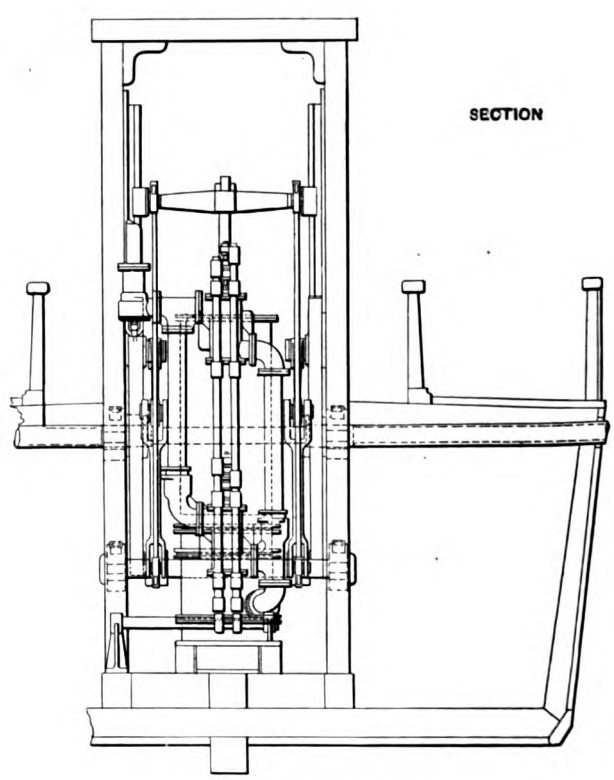
No attempt was made to reproduce the original boiler of the *Clermont* exactly, because such a boiler would not be allowed in operation to-day by the steamboat inspection service. The boiler used on the replica is an ordinary externally-fired horizontal tubular boiler, 5 feet 6 inches diameter, 16 feet long, with ¼-inch shell, 5/16-inch heads and forty-six 4-inch tubes, designed for a working pressure of 25 pounds per square inch.



MIDSHIP SECTION OF THE CLERMONT.

As showing the extent of the theoretical knowledge of naval architecture and marine engineering in Fulton's time the following extract from one of Fulton's letters is of interest:

"My first steamboat on the Hudson's River was 150 ft. long, 13 ft. wide, drawing 2 ft. of water, bow and stern 60 degrees; she displaced 36.40 cubic ft. equal 100 tons of water; her bow presented 26 ft. to the water, plus and minus the resistance of 1 ft.; running 4 miles an hour.



END VIEW OF THE MAIN ENGINE.

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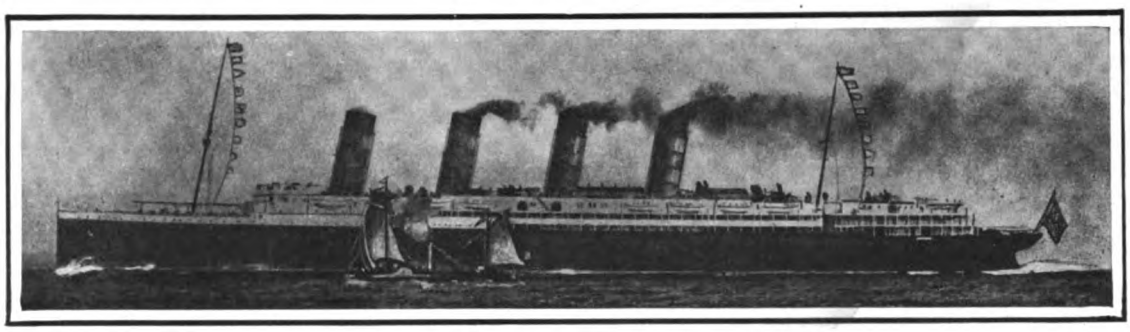
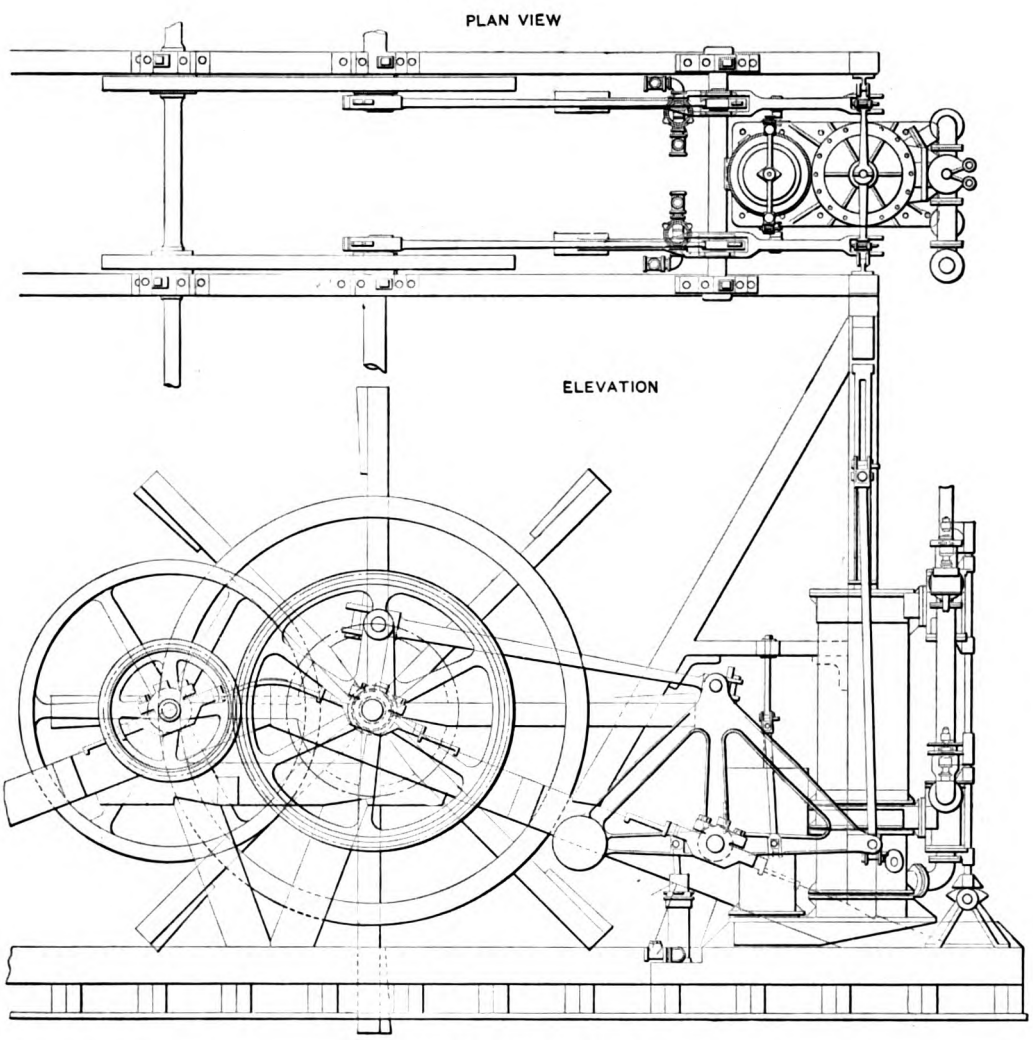


THE MAURETANIA AND THE CLERMONT, SHOWING A CENTURY'S PROGRESS IN STEAM NAVIGATION.

12.37 lbs. multiplied by 26, the bow of the boat.....	321 lbs.
Friction on 2,380 superficial ft. of bottom and sides, 7.50 lbs. or 50 superficial ft.....	352
Total resistance of the boat, running 4 miles an hour	673
A like power for the propellers.....	673
Total power felt at the propellers.....	1346
The boat running 4 miles an hour is 6 ft. a second; this is three times faster than the piston; hence multiplied by.....	3
Necessary power of the engine, the piston running 2 ft. a second.....	4038 lbs."

The first voyage of the *Clermont* was begun on Aug. 17, 1807, the boat proceeding from New York up the Hudson River for 110 miles during the first twenty-four hours. The average speed thus far had been about 4.6 miles per hour. Continuing the journey on the following day the *Clermont* proceeded to Albany, a distance of 40 miles, in eight hours. The running time for the entire trip of 150 miles from New York to Albany had been thirty-two hours, or at the rate of nearly 5 miles an hour. The return trip was made in thirty hours' running time, or an average of just 5 miles an hour. This same trip is made to-day in the regular running time of nine and one-half hours by boats capable of an average speed of 20 miles an hour.



MAIN ENGINE OF THE CLERMONT.

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THE DEVELOPMENT OF THE SAILING SHIP.

BY SYDNEY F. WALKER.

Forty years ago, when the writer was serving in H. M. Navy, the sea was covered with sailing ships of all classes, ranging from the fore-and-aft schooner to the stately full-rigged ship. When crossing the trade winds, or when running them down, one constantly met a stream of ships and barks ranging from 500 up to about 2,000 tons, with every stitch of sail upon them. The navies of the world also were propelled by sails. It is true their ships carried steam, but it was only as an auxiliary, and the horsepower was very small. Frigates of 2,000 tons, with only 500 horsepower, were the largest naval sailing ships afloat. To-day, however, the sailing ship is steadily disappearing, although a few four and five-masters may stil be seen, and small fore-and-aft rigged sailing vessels are quite numerous on the Atlantic and Pacific coasts of the Americas and in the neighborhood of Australia, China and the Islands. The fore-and-aft rigged craft will probably be the last to succumb, and in the writer's opinion the conqueror will not be steam, as was the case with the square-rigged vessels, but oil or producer-gas power.

GALLEYS.

The history of ships goes back as far as history itself. The Greeks, Romans and Carthaginians not only had fleets, but important battles were often fought at sea between the fleets. The parents of the Carthaginians, the Phœnicians, also were great sea rovers. Ships of various kinds were used upon the Nile from the very dawn of history, and they appear also to have been used by the Assyrian and Babylonian kings on the Tigris and Euphrates, and upon the canals that were dug all over Mesopotamia.

Although it is not possible to obtain very accurate accounts of the ships of those early days, we know that they were almost entirely propelled by oars, and, further, that slaves were employed in them. The galleys, in the case of the Greeks at any rate, appear to have been developed on very much the same lines as the old three-deck men-of-war of the 18th and 19th centuries. In order to obtain greater speed, and to enable a galley to carry a larger number of fighting men, a larger number of oars were necessary, and they appear to have been obtained by increasing the free board of the galley, and placing the tiers of benches, or thwarts, one above the other, presumably separated by decks, each tier carrying a bank of oars, each oar being manned by a certain number of slaves. The Greeks are stated to have employed as many as five banks of oars, vertically one above the other. Alexander the Great had galleys with four and five banks, and the Carthaginians used five banks and a sail. The Greek trireme, carrying three banks of oars, was apparently quite common. The galleys of those days employed sails only when the wind was favorable, and sails were not always carried.

Galleys appear to have persisted down to the Middle Ages. The Genoese and Venetians employed them, apparently some time after other nations had adopted sailing ships. The Genoese and Venetian galleys, in which a very large trade was carried on, and in which war was also pursued, were usually 150 feet long, about 20 feet wide at the widest part, and carried two masts, each with a lateen sail. They had a forecastle in the fore part of the ship, where the fighting men were accommodated, a poop or after castle at the stern, where the knights and officers were carried, and a short deck, just forward of the poop, probably the origin of the term quarter deck, that has come down to us. The galley was used in France down to the 18th century.

The galleot was a large galley, with poop and forecastle, employed by the Barbary corsairs, and the Spanish and Portuguese galleons and the Neapolitan galleasses grew from the old Venetian and Genoese galleys by the ordinary process of development. The addition of the poop and forecastle and quarter deck led to a complete deck above the waist, where the rowers sat, arranged to carry a second crew of rowers, and when artillery came into use these decks were employed to carry guns.

The Viking ships, which carried the Norsemen who conquered Great Britain, the northern coast of France, which is now called Normandy, and other parts, were galleys. One has recently been found in Norway, and is preserved at Christiania. It is clinker built, 78 feet long, 7 feet beam amidships, 5¾ feet deep. Its draft was less than 4 feet, and it carried thirty-two oars and a mast 40 feet high. The hardy Norseman, the writer understands, did not venture very far out of sight of land, and this was the characteristic of practically the whole of early navigation. Sailing also was not at all common in the early days of ships. The wind was not understood, and it was very much feared. It was used when it was available, strictly to run before.

It is not clear when sails became the important part of a ship's equipment that they were in the latter part of the 18th and nearly the whole of the 19th century. Probably it was a gradual development. In old prints the ships in which William

FIG. 1.—SHIPS OF THE 14TH AND 15TH CENTURIES.

the Conqueror crossed the channel are represented with lug sails. Evidently they were only arranged for running before the wind. The ships of the time of the 14th and 15th centuries, Fig. 1, are represented also with sails only intended to be used before the wind. The ships of William the Conqueror, and right down to the 15th century, are represented as practically large, open boats, with towers or structures at the bows and sterns, corresponding to poop and forecastle, with a mast amidships.

FIRST IMPORTANT PROGRESS IN SHIPBUILDING.

It was not until the time of Henry VII. and Henry VIII. that any really important progress appears to have been made in shipbuilding. In fact, though Alfred is usually understood to be the father of the British Navy, Henry VIII. might be more correctly so described. In his time the *Henri Grace-à-Dieu,* shown in Fig. 2, was built. It will be noticed that it carries four masts, the fore and after castles, the latter being called the poop and the waist, and that there is the heavy superstructure which characterized all ships of that day. Apparently she carried lower sails, courses as we should now term them, on all four masts and topsails. She also appears to have carried a sail corresponding to what afterwards was called the jib, and another corresponding roughly to the spanker. The round tops shown on each of the masts had been introduced into previous ships for the use of the pilot.

In Henry VIII's time ships were still in a very crude condi-

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tion, but important developments were going forward. The *Henri Grace-à-Dieu* was of 1,000 tons burden, and is stated to have had two decks. Probably what is meant is that the large superstructure of the poop and forecastle practically formed a second deck. About this time, or a little later, top-gallant sails appear to have been introduced, and also some of the fore-and-aft sails, the jib, trysails and spanker, which afterwards became so useful. Developments went on during

FIG. 2.—THE HENRI GRACE-À-DIEU.

the reign of Elizabeth, and, as is well known, the superior sailing qualities of British ships enabled them to harass the bulky Spanish ships.

The Spanish galleons were built in very much the same style as the *Henri Grace-à-Dieu,* with high poops and high forecastles and with quarter and half-decks, and in several cases with two gun decks in addition. The poop and forecastle were originally castles built at the stern and bows. The half-deck was a short deck extending forward from the poop towards the forecastle, and the quarter-deck was another short deck above the half-deck. The quarter-deck, which has become almost historic, would naturally be the point where the officers, who usually lived in the poop, met deputations from the men, and where the men who had to see officers would find them. The half-deck in men-of-war at the time the writer was in the navy was the after portion of the main deck, the principal gun deck, immediately under the quarter-deck.

TWO AND THREE-DECK VESSELS.

In James I.'s time many improvements were made in the design of ships by Sir Phineas Pett, who was practically the first scientific naval architect, the first man who thoroughly studied the problems involved in shipbuilding. One of the earliest reforms introduced by Pett was the doing away with a large portion of the heavy superstructures that have been mentioned, and that were carried by practically all ships up to that date. Other important improvements were made. Charles I. also, though he was so unfortunate in his government, did a great deal for the navy, following in his father's footsteps. It was in his reign that the first three-decker, the *Sovereign of the Seas,* shown in Fig. 3, was built. She carried a very long bowsprit, a very long prow, three distinct gun decks, besides a very high poop and a high forecastle. The half and quarter-decks also are easily made out. She carried four masts. Each mast had a round top just above the lower yard, and another top above the topsail yard. All but the after mast carried lower sails, or courses, topsails and top-gallant sails. The masts had been made all in one piece, lower mast and topmast, but in Sir Walter Raleigh's time the topmast appears to have been made a separate piece, stepped in the top, and arranged so that it could be sent down, and in later times the top-gallant mast, which included in still later times the royal pole, was also made separate. The small round tops shown at the head of the topmasts of the *Sovereign of the Seas* afterwards became the cross trees of the modern sailing ship. The bowsprit appears to have been first introduced in the reign of Edward III., but it was not until very much later that it was made use of in the manner in which it was afterwards employed, to spread fore and aft sails.

A point may be noted here with reference to the mercantile marine. In the early days of shipping there was practically no mercantile marine, in the sense we now understand it. Men went to sea for the purpose of trading in ships found by themselves or by adventurers, and in most cases the ships were heavily armed, amounting practically to warships. In later times, the development of ships intended solely for trading took on its own special lines. Trading ships had to be built for speed and for carrying as much cargo as possible. Sea passenger traffic in those days was very small. As time went on it also gradually developed, and ships were developed to meet its requirements, till they have reached the enormous liners of to-day. The advent of steam has, of course, fostered the passenger traffic, partly because steam enables passages to be made in so much shorter time, and steamers can be made more comfortable for passengers than sailing ships, though for the seaman, for the man who loves the sea, the reverse holds good.

The navies of the world were practically developed on much the same lines. The necessity for carrying more guns could only be met in those days by building ships with more decks, and so, although the *Sovereign of the Seas* was only imitated at a considerably later period, and was herself cut down considerably before the expiration of her useful life, the two and three-decker came into existence.

It was not, however, till the rivalry between Holland and Great Britain on the one hand, and between France, Spain and

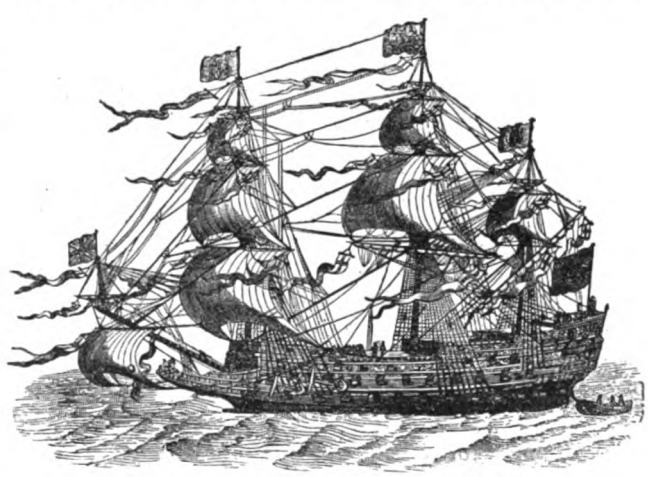

FIG. 3.—THE SOVEREIGN OF THE SEAS. THE FIRST THREE-DECKER.

Great Britain on the other, was fully developed in the 18th century, that the building of ships of war settled down to certain definite lines. The length of the keel of the *Sovereign of the Seas* was 128 feet, her beam was 48 feet, her total length from the end of the beak to the end of the stern was 232 feet, and her burden was 1,637 tons. Other three-deckers were built at various dates, among them the *Victory,* in 1786, whose length was 186 feet, burden 2,100 tons, and which carried one hundred 32-pounder guns; the *Duke of Wellington,* in 1849, of 3,771 tons, 240 feet long, carrying 131 guns; the *Marlborough,* in 1850, of 4,000 tons, with a steam-driven screw as an auxiliary, and in 1860 the last of the old three-deckers, the *Victoria,* was built. The three-decker carried from 100 to 131 guns, according to her size.

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In the period mentioned, from the middle of the 18th century up towards the end of the 19th century, in addition to three-deckers there were a fair number of two-deckers carrying 74 and 80 guns.

RIGS.

The two and three-deckers were fully rigged. They carried three masts, a bowsprit with jibboom and flying jibboom. Each mast carried a topmast, top-gallant mast and royal pole. On the fore and main masts were carried the following square sails: Courses secured to the fore and main yards, topsails spread between the topsail and lower yards, top-gallant sails spread between the top-gallant and topsail yards, and royals spread between the royal and top-gallant yards. The mizzen mast, as the after mast was called, carried the same sails, with the exception of the lower one. The lower yard on the mizzen mast was called the cross-jack yard, the yards above it being called mizzen topsail, top-gallant and royal yards, respectively. There was no cross-jack course. In addition to these sails there was a three-cornered jib, secured to a stay held between the head of the fore mast and the end of the jibboom; a flying jib, carried upon a stay, secured to the end of the flying jibboom, and for bad weather a fore-staysail, a three-cornered sail, secured to the fore-stay, which was stretched between the head of the fore mast and the bows of the ship. Abaft the mizzen mast was carried the spanker, a sail similar in form to the mainsail of a schooner, and stretched between a gaff, a boom and the mizzen mast. The spanker was of great service in keeping the ship to the wind when sailing close hauled, and particularly in tacking. Storm trysails were also carried on gaffs attached to the fore and main mast, similar in shape to a schooner's fore sail, and spread in a similar manner. They were only used in bad weather. In addition, all ships carried another set of sails for light weather when the wind was abeam or abaft the beam, called studding sails, pronounced "stunsails." They were oblong in shape, and formed continuations of the fore and main topsails and top-gallant sails. They were stretched between studding sail booms, run out at the ends of the lower and topsail yards and yards which stretch their heads.

FRIGATES, CORVETTES AND SLOOPS.

In addition to two and three-deckers a certain number of frigates were carried by all nations. The frigate of those days corresponded to the cruiser of to-day. It acted as a scout, but a large number of them were of sufficient power to defend themselves if attacked, and occasionaly to take their place in the fighting line on emergency. In later times, in the late sixties and seventies, frigates were the largest ships of the Old World patterns to keep the sea.

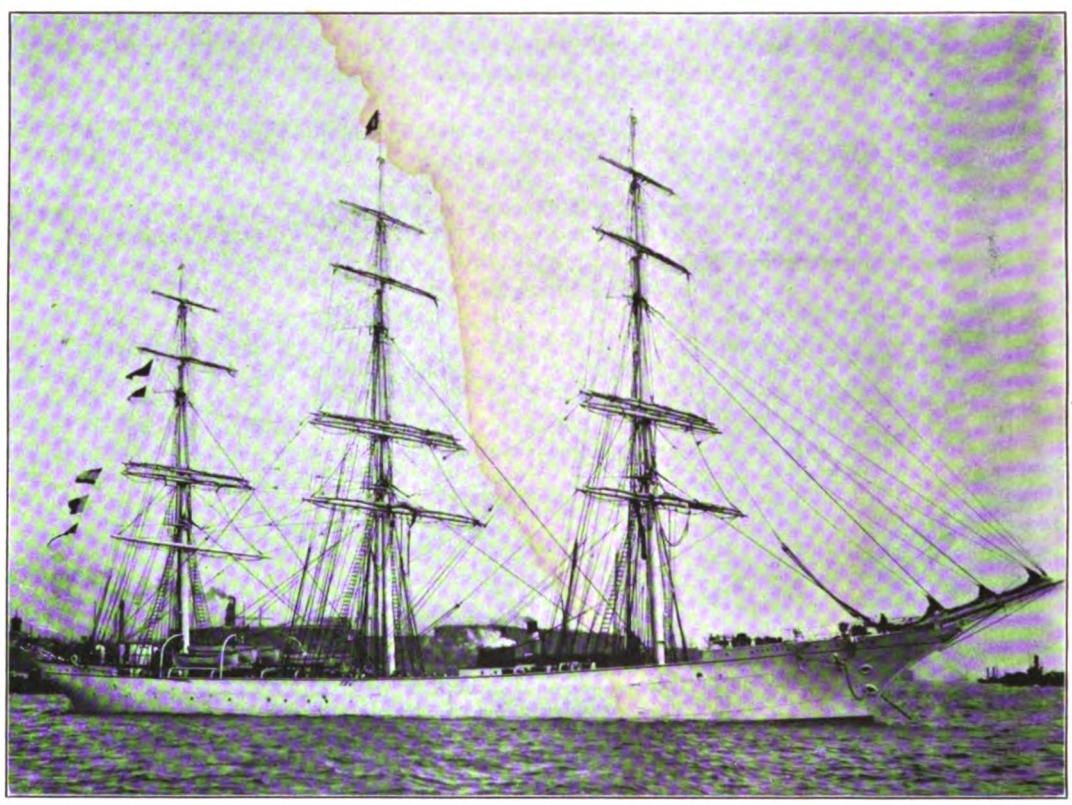

FIG. 4.—MODERN TYPE OF SAILING VESSEL. THE WHITE STAR TRAINING SHIP.

The frigate was built on exactly the same lines as the two and three-deckers. She had one gun deck, known as the main deck, and in addition she carried guns on the quarter deck, sometimes on the poop, if there was one, and on the forecastle. The frigates were ship rigged exactly the same as two and three-deckers, the only difference between them being that they did not stand so high above the water and did not carry so many guns.

In addition to the above there was a class of ships in the navy in those days known as corvettes. They were usually ship rigged, and would correspond to second-class cruisers of the present day. They only carried guns on the upper deck, quarter-deck, forecastle, etc. There was a still smaller class of cruiser, as it would now be termed, known as a sloop. It was sometimes ship rigged and sometimes bark rigged. Sloops also only carried guns on the upper deck, and were similar to corvettes, except that they were smaller. There was still another class of vessels carried in most navies, known as gun boats. They carried three masts, but usually only square sails on the fore mast. Practically they would be three-masted topsail schooners. They carried a few guns on the upper deck, the men and officers living on the deck below.

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In the mercantile marine, which had fully developed by the time referred to above, ships were built on very much the same lines as those for the navy, except that there were no two or three-deckers, and there were no gun decks. Large ocean traders, equal in size to frigates and ship rigged, were built for carrying cargo and a certain number of passengers, the accommodation for the latter, as explained, steadily increasing as the traffic increased. In addition there were a very large number of smaller vessels, some ship rigged, some bark rigged, some rigged as brigs, some as brigantines, topsail schooners and fore-and-aft schooners. The tonnage of barks and ships ranged from about 500 to up to 2,000, brigs, brigantines and schooners ranging from a few hundred tons downwards. The brig carried two masts, with square sails on each and the same fore-and-aft sails as the ship. The brigantine carried two masts, with square sails only on the fore mast, but she carried a full complement of sails there, and in some cases top-sails, top-gallant sails and royals on the main mast. Topsail schooners carried two masts, and had square topsails on the fore mast in addition to their fore-and-aft sails. Fig. 4 shows the White Star Company's training ship for their cadets. It has the latest sailing ship fittings. In addition to the usual sails carried by ship-rigged vessels, as described above, merchant ships often carried additional sails above the royals, for getting more speed out of the ship, when it was safe, as when running down the trade winds. The sails immediately above the royals were known as sky sails. Sometimes sails were carried even above those, known as moon rakers, and so on.

CONSTRUCTION OF WOODEN SAILING SHIPS.

Wooden sailing ships were constructed on very much the same lines as iron ships are, with the necessary difference that the wooden framework, etc., had to be very much thicker and very much larger, the whole skin of the ship, and the different parts entering into its construction, taking up very much more room than in iron or steel-built ships. In the wooden ship there was first the keel, which was of teak, with a stem and stern post securely scarfed and bolted to it, and with the ribs, or timbers as they were usually called, stepping into it. On top of the keel, and holding the lower ends of the timbers in their place, was the keelson, another piece of stout oak. On the inside again, forward, was the stemson, and aft a similar timber, holding the outer timbers, running between stem and stern, in their place.

The ribs were the result of careful design, and were usually either cut out of solid timber or bent into their form by special appliances. Upon the careful design, careful construction and careful fixing of the ribs depended the capacity of the ship, its stability, its speed and its ability to stand bad weather. Great care was taken with the shape of the ribs forming the bows, and again those forming the run near the stern. The construction of the after part of the ship, allowing a clear passage for the water displaced by the bows as the ship cleaves her way, has as much to do with speed as the shape of her bows. Naturally, the shape of the bows also was the subject of considerable thought and skill, and old seamen used to say that for speed the shape of fishes like the dolphin should be taken as a guide.

The skin of the ship was completed by outside timbers, bolted to the ribs secured to the stem and stern post, being held in their places by the stemson and sternson. There was also usually an inner planking of wood connecting the ribs with the stem and stern post, and the keelson fore and aft. The beams, which stretched across the ship at intervals, performed the double office of supporting the different decks and of assisting to bear the strains to which the ship's timbers were subjected.

The construction of men-of-war differed from that of merchant ships, in that men-of-war were designed to carry guns and to provide accommodation for men, and therefore the interior of the ship was divided up by as many decks as possible, while with merchant ships the great object was to obtain as large a space as possible under the upper deck, in order to stow cargo. With the development of passenger traffic, merchant ships also became more and more divided up by decks, to provide accommodation for the passengers, and the construction more and more approached that of men-of-war. In men-of-war there were holds below the lowest decks in which the stores required by the ship—provisions, ammunition and spare sails, boatswain stores of all kinds—were kept.

TRANSITION FROM WOOD TO STEEL-BUILT SHIPS.

The first steps in displacing wood by iron and later by steel were taken by navies in building what were known as iron-clads in the sixties. H. M. S. *Caledonia* and others were really wooden ships with a protection of iron outside of the wood, the object being to offer a greater resistance to the rifled shot and shell which was then gradually being developed. In those days steel was thought to be unsuitable for the work, because the steel plates which had been made and applied to the protection of ships had been found to break up when pounded by rifled shot.

At the same period the transition from sail to steam was in progress. Nearly every man-of-war of those days was fitted with a screw and with a certain amount of engine power, but it was strictly auxiliary. The screw was made to be pulled up out of the water, in a well made specially for the purpose, and steaming was resorted to as seldom as possible.

Several experimental ships were built by the British and other navies about the same time, and a number of new classes of ships were introduced in America during the civil war, these leading indirectly to the present form of modern battleship.

In the mercantile marine the development appears to have followed very much the same lines as in the navy. Steam was first applied, hardly as an auxiliary, in the same sense as in the navy, but sails were not dispensed with, nor even curtailed, for a very long period. In the *Great Britain*, which was built in 1852, and which had four masts, steam was intended to be the motive power, but it was to be assisted as far as was possible by the sails. Steam was applied in this way by the great steamship lines trading between Great Britain and the United States, and between Great Britain and Canada, and between Great Britain and Australia. As time went on, and as the ships became larger, and, again, as more speed was demanded, the engine power was increased, and the sails became gradually of less and less importance, till they finally disappeared.

The transition from wood construction to first iron and then steel has been gradual but continuous, and it has been contemporary, or nearly so, with the development of steam. It may be taken, in fact, that the development of the manufacture of steel, the development of steam power for ships, and the adaptation of steel for building ships have gone on together, and they all date practically from the invention of Bessemer steel.

The modern four and five-master is built of steel, and differs very little in construction from that of the modern steam tramp, except that as there are no engines and boilers more room is provided for cargo, and there is no necessity for providing in the structure of the vessel for the strains set up by the vibration of the engines. On the other hand, provision has to be made for the masts, sails, etc., and for the rigging, and also the ship as a whole, should be built more strongly than would be necessary with a steamship, because the sailing ship cannot lie head to wind and head to sea in bad weather.

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THE HALF MOON.

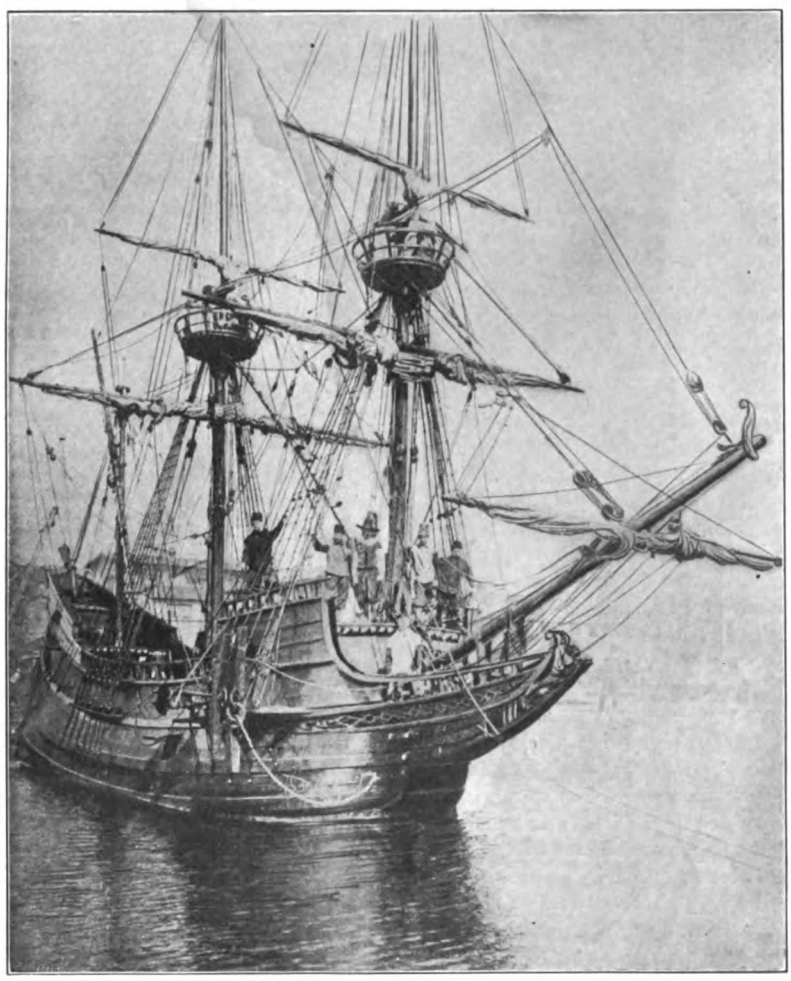
Three hundred years ago Henry Hudson sailed into New York harbor and began the exploration of the river which has since borne his name. This was Hudson's third voyage of discovery, the main object of all his voyages being to discover a northwest passage to the Pacific Ocean and China. On his two previous voyages, which were carried out under English auspices, he endeavored to reach China by passing, in one case, between Greenland and Spitzbergen and across the polar region, and in the other case between Spitzbergen and Nova Zembla. Both of these voyages were failures as far as their original object was concerned, but their secondary results were important, for Hudson's discoveries of Arctic whale fisheries led to the establishment of very valuable sea industries both among the Dutch and the English.

The third voyage, which resulted from a contract with the Dutch East India Company, led to the exploration of the Hudson River and the settlement of New Netherland. This voyage, like the previous ones, was an attempt to discover a northwest passage to the Pacific.

The vessel in which Hudson made this memorable voyage was the *Half Moon,* or, as it was spelled in Dutch, *De Halve Maene.* The *Half Moon* was a small vessel even for her own times, and as compared with the monster ships which to-day enter New York harbor she is hardly more than a midget. Few people would care to venture to sea to-day in such a craft, and that Hudson was able to complete successfully such a long and hazardous voyage in such a boat speaks well for his skill as a navigator.

The *Half Moon* was only 74.54 feet long over all, and 58.70 feet long on the waterline. Her beam was 16.94 feet, her depth 10.08 feet (English measure), and her draft 7.03 feet. A replica of this famous ship has been built by the people of Holland to take part in the forthcoming Hudson-Fulton celebration at New York, and through the courtesy of the Hudson-Fulton Celebration Commission we are able to present photographs and the following detailed description of this ship as an example of the development of naval architecture 300 years ago.

The ship has three masts; on the foremast are fixed the fore-topsail and foresail (the "blind sail" is on the bowsprit);



BOW VIEW OF THE HALF MOON.

on the mainmast is the maintopsail and mainsail, while on the mizzen mast a lateen sail is fastened.

The captain's cabin under the poop has been built on the upper deck. In the cabin, under the berth, is a chest, beautifully bound, containing books. On the table lies a sea chart and a copy of the contract with Hudson for this voyage, copied from the minute book of the directors of the East India Company of the Chamber of Amsterdam, dated Jan. 8, 1609. Around this are the dividers and little pieces of wood for measuring Further, there is in the cabin a Jacob's staff, really a very primitive sextant, by means of which the navigators 300 years ago determined the latitude with a fair degree of accuracy. Above the captain's cabin is the one for the mate, still smaller and simpler. The best observation point in the ship is

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the poop, from which the whole ship can be seen. Forward is the forecastle, the sleeping place of the crew, with five berths, in each of which if necessary two men can sleep; under the bowsprit is the galley, where the sailors, for punishment, were exposed to the seawater, and where was fastened the "blind sail," so called because it interrupted the pilot's view. On the deck are two blocks, to which the ropes are fastened. One of them has the ordinary head of a seaman, with his mouth open as if yawning; further back is the steersman's platform, over which a little roof has been built for the steersman; the rudder being moved by the whipstaff which is bound to the tiller. The steersman has before him a compass, a sand-glass and a log-glass.

Under the upper deck is the 'tweendeck or "verdeck." In this are the hawse holes for the anchor. Further, there is the very primitive kitchen and the berth for the cook, a sail room, and at the stern the gunner's room, where the powder is stored, the bread room and the berth for the steward. Underneath is the hold for the provisions, the drinking water, the cables and, lastly, for the cargo.

The armament consists of two small and two large cannon. On the deck near the railing stand the small ones, that is, swivel guns, also called "kamerstukjes"; these are 100-pound pieces. In the 'tweendeck space are two heavy pieces of 800 pounds each.

Part of the equipment is a small ship's boat similar to a cutter, which is fastened to the deck above the main hatch aft of the foremast.

The *Half Moon* has at its rail the East India Company's flag, the national tri-color, with the well-known monogram, V. O. C.—Veroenigd Oost-Indische Compagnieen (the United East India Companies)—in the white stripe above which is the letter "A," an indication that it was the Amsterdam Chamber which commissioned Hudson. On the bowsprit is a small jack of orange, white and blue. The flag of Amsterdam flies from the foremast; the state flag of the Province of Holland (gold with red lion) is on the mainmast, and a small vane on the mizzenmast.

There are two hatches, one forward and one aft. The forward hatch is scarcely large enough for a man to pass through, and the after one is little better. The hold extends the entire length of the vessel, and a wood pump tube runs down from the upper deck to the bottom of the hold, to serve the purpose of a bilge pump. This pump tube is about a foot in diameter, and is hollowed or bored out from a tree trunk. It is operated from the upper deck by means of a wooden handle.

STERN VIEW OF THE HALF MOON.

It is remarkable how the crew were able to handle the vessel when the quarters on board were so cramped. Forward of the companionway the space between decks was only about 4 feet, and aft it was only a foot higher, scarcely permitting one to stand upright.

After spending about a month exploring the river up as far as he found it navigable, Hudson returned to England, and a year later, again under English auspices, set forth on his fourth and last quest of the northwest passage. This resulted in the exploration of Hudson's Bay, but Hudson himself was abandoned by a mutinous crew.

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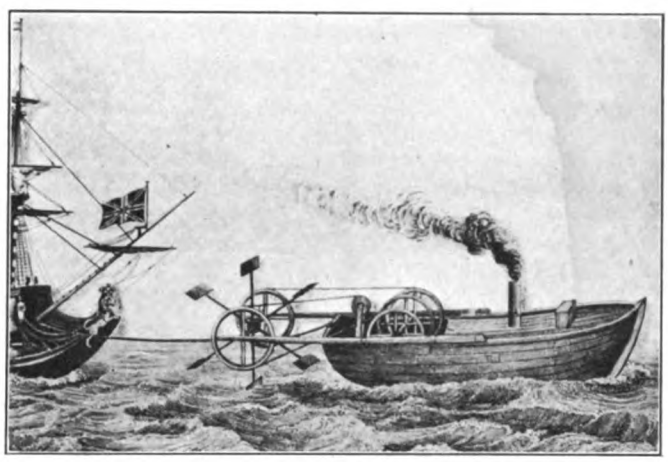
PIONEER PADDLE-BOATS IN BRITAIN.

BY G. PINHORNE, M. I. N. A.

To "make a Boate to goe without Oares or Sayles * * * * against Wind and Tyde" is an oft-recurring claim in the earliest-recorded speculations or experiments of philosophers and mechanics. It perhaps would be invidious, and certainly controversial, to urge originality, or even comparative importance, to any one of these. Each and all, the known world over, contributed a quota to the perfecting of our knowledge of mechanical appliances or the properties of steam, and thus helped to make steam navigation an accomplished fact at the commencement of the nineteenth century.

Foremost among the early patentees of ideas relating to steam-propelled vessels may be fairly mentioned Jonathan Hulls, the Gloucestershire yeoman—our selective preference being largely influenced by his detailed descriptions and draw-

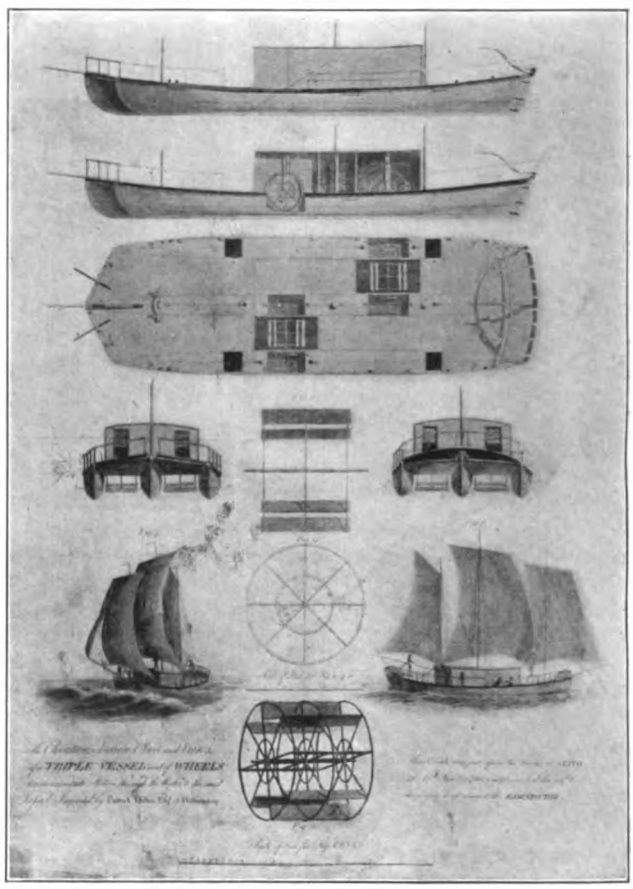


JONATHAN HULLS' TUGBOAT—1736.

ings, as well as by the immense suggestiveness of his ideas in the light of subsequent progress. The illustrated pamphlet, published in 1737, describing his invention, depicts a barge-like vessel carrying a large paddle-wheel, supported upon long davits abaft the stern. This wheel was rotated by a system of ropes and ratchet-pulleys, driven by an atmospheric engine of the Newcomen type. It has a single cylinder 30 inches in diameter, but the double-acting principle was obtained by the interesting expedient of raising a weight, on its working stroke, equal to one-half its effective pull, and then absorbing this energy on its return stroke. Experiments were supposed to have been made on the River Avon; but, if so, they were apparently disappointing, for Hulls' schemes in this direction were entirely abandoned.

Fifty years elapse before we again find tangible evidence of development on practical lines. Curiously enough the man primarily responsible for this—the first practical step in steam navigation—was a man deeply absorbed in the problem of improved methods of boat-propulsion by muscular power.

Patrick Miller, of Dalswinton, Scotland, had several vessels of novel design constructed at Leith in 1786-'87. Besides having the unusual features of twin or triple hulls, each of these vessels was fitted with man or wind-driven paddle wheels. One of the largest and most successful of these craft was a double-hulled vessel 100 feet long and 31 feet broad. Each hull was about 12 feet broad, leaving a 7-foot space between, in which were arranged, tandem-fashion, five-paddle wheels about 7 feet in diameter. Each wheel was worked by a separate capstan on deck: the quaint contemporary description of the intervening mechanism could not, perhaps, be improved upon by paraphrase. "On the lower part of the capstern was a fixed wheel with teeth pointing upwards to work in a trundle fixed on the axis of the water wheel. The diameter of this wheel is equal to 3½ diameters of the trundle, so that one revolution of the capstern produces three and one-half revolutions of the water wheel." With thirty men employed, a speed of 4.3 knots was attained. Arrangements were made for lifting the paddles out of water when under sail. This vessel is recorded to have made a satisfactory voyage across the North Sea to Stockholm in very rough weather. Windmill motors were tried by Miller, and



PATRICK MILLER'S DOUBLE AND TRIPLE-HULLED PADDLE BOATS.

also winches and crank-handles as alternative manual machines. An inset to the photograph of the above ship shows a number of details of the *Edinburgh*, a triple-hulled design by Miller, which was driven by two 6-foot paddle wheels.

It was while engaged in these experiments that the idea of using steam as a motive power was suggested to him by a Mr. Taylor, and with it the name of a neighboring mining engineer, William Symington, who had recently invented "a steam engine on principles entirely new." Symington was therefore approached, agreed to the proposals, and by this happy collaboration of engineer, financier, enthusiast and mutual friend, was produced the first circumstantially described and propelled steamship.

A small double-hull boat 25 feet in length and 7 feet extreme breadth was prepared by Miller, and aboard this vessel Symington's machinery was placed in October, 1788, the engines being upon one hull and the boiler upon the other. As indicated by our sectional view of this novel craft, the two paddle wheels were driven by wheels and chains and arranged one before and one abaft the driving machinery. It was an atmospheric engine having two open-topped cylinders each, only 4 inches in diameter, with a 9-inch stroke. The valve

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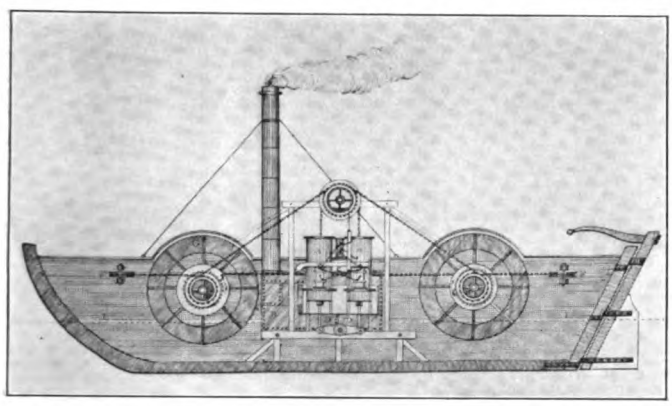
boxes were fixed at the lower ends, and the steam and exhaust valves actuated by "tappet" mechanism. A jet condenser was used, and the air pumps, curiously formed at the lower ends of the main cylinders, were fitted with separate and inverted pistons connected by a small rocking-lever. On each paddle shaft were two loose pulleys with ratchet teeth,



INBOARD PROFILE OF SYMINGTON'S AND MILLER'S FIRST BOAT WITH THE "ORIGINAL MARINE ENGINE" INSTALLED—1788.

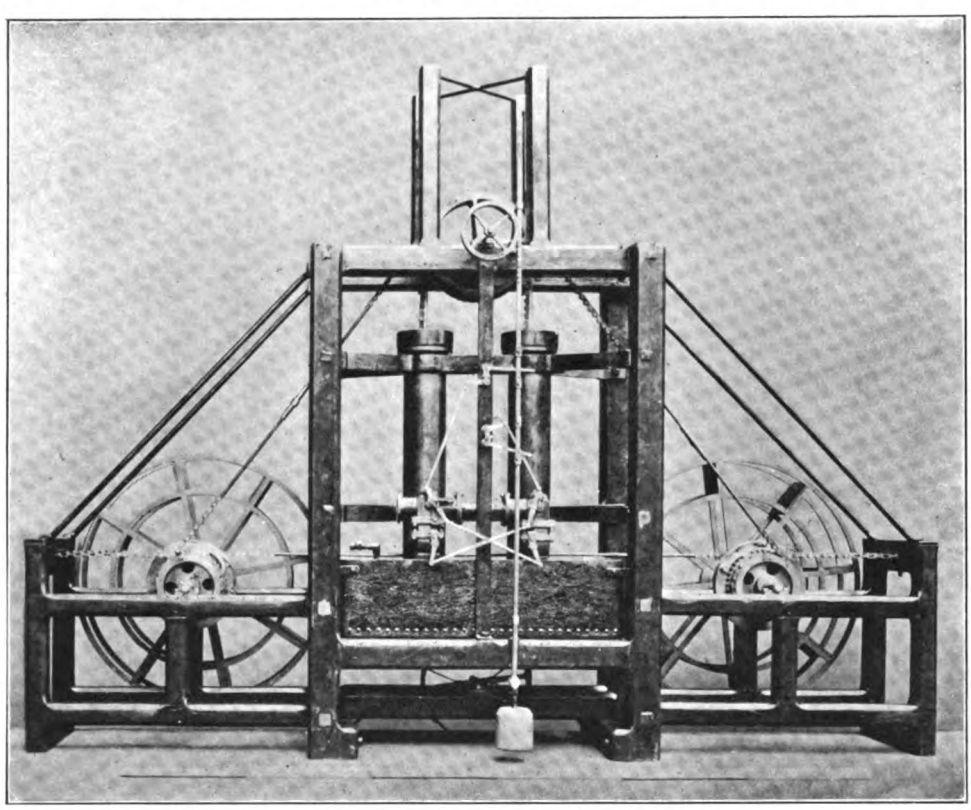
which engaged alternately with chains from the central driving drum and thus gave continuous motion in one direction.

Experiments on Dalswinton Lake with this boat were of such a character as to justify a larger equipment. In the following year, therefore, a similar set of engines, with cylinders increased to 18 inches in diameter, was made and fitted upon a much larger craft on the Forth and Clyde Canal, with the result that a speed of between 6 and 7 knots was readily obtained. At this stage, however, Miller appears to have been dissatisfied with the type of engine used, and the partnership ended.

The first set of these engines, which may fairly claim to be "the original marine engine," has been preserved in a remarkable manner. After changing ownership on various occasions and being finally condemned as scrap metal, most of the pieces were collected together by the late Bennet Woodcroft, Esq., F. R. S., inventor, and author of "The Origin and Progress of Steam Navigation, etc.," who delivered them into the hands of Messrs. Penn & Sons, the well-known engineers of Greenwich; here the engine was successfully rebuilt and again run under steam in 1854. A separate photograph of this interesting relic is reproduced: the original may be seen in the machinery galleries of the Victoria and Albert Museum, South Kensington.

In 1801, a Lord Dundas, who was largely interested in the development of the Clyde and Forth Canal, asked Symington to design and build an experimental steam tug for this service as a substitute for horse haulage. Symington accepted, and, profiting by his early experiences, as well as by the more recent advances in steam-engine details made by James Watt and contemporary engineers, produced an entirely new type of machine and, it is to be noted, attached it directly to a crank on the axis of his paddle wheel. Combining with these innovations an improved boat and paddle, he patented the whole conception in October, 1801. This was the famous *Charlotte Dundas*.

A cursory examination will convince that this engine was a remarkable step towards simplicity of construction, if it were not indeed well abreast of marine engine design for the next half-century. The hull, too, presents a not unfamiliar appearance to those acquainted with shallow-draft stern wheelers of quite recent date. As a whole, the *Charlotte Dundas* well justifies her claim to have been the "first practical steamboat." The machinery itself may be termed epoch-marking, as applied to this purpose—a horizontal direct-acting engine with connecting rod and crank, the lever or beam being specifically abolished; a piston rod kept in parallel motion by a roller or slide, and last, but not least, an internally-fired boiler. The



SYMINGTON'S ORIGINAL MARINE ENGINE.

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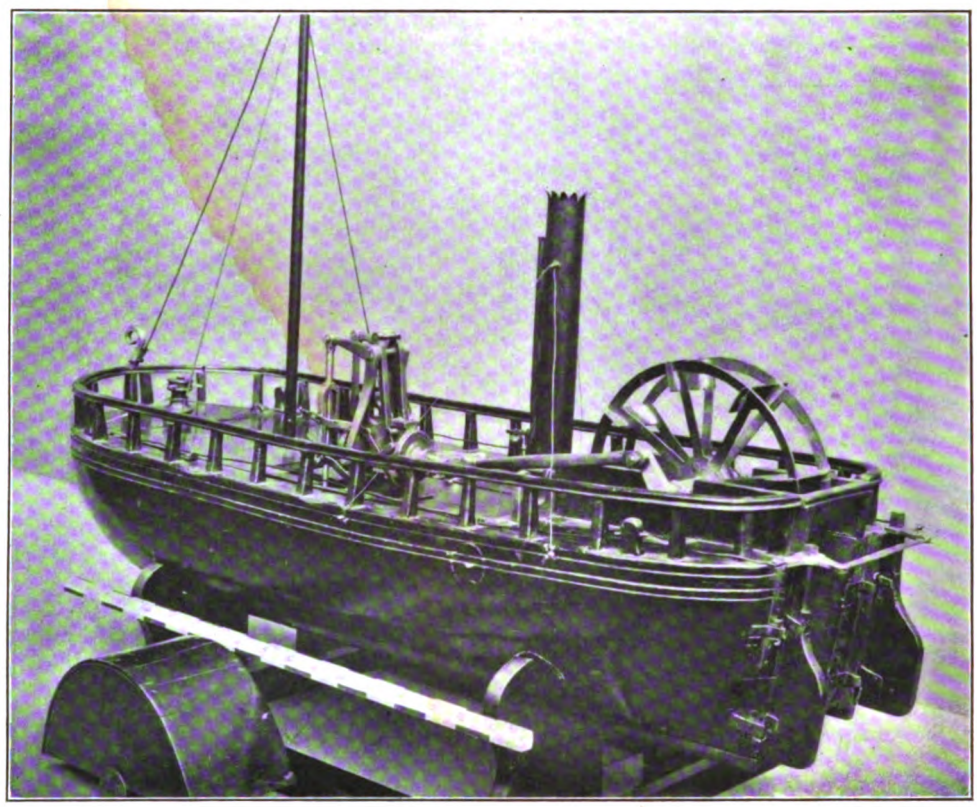
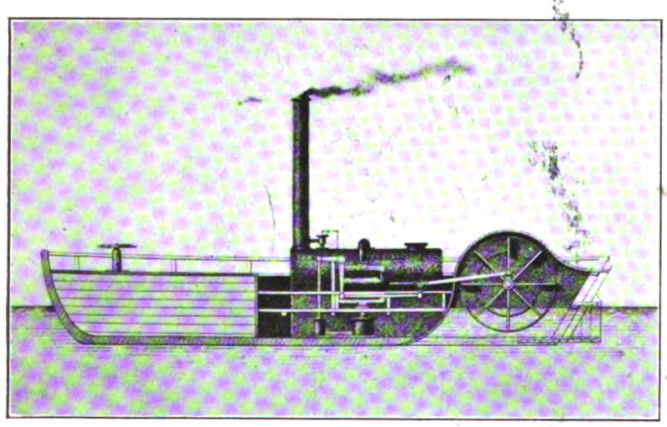
single cylinder of the engine was 22 inches in diameter, with a 4-foot stroke, and an estimated horsepower of 10. Condenser and air pump were below deck, the latter worked by a bell-crank from the cylinder cross-head.



MODEL OF THE CHARLOTTE DUNDAS, SYMINGTON'S FIRST PRACTICAL STEAMBOAT—1801.

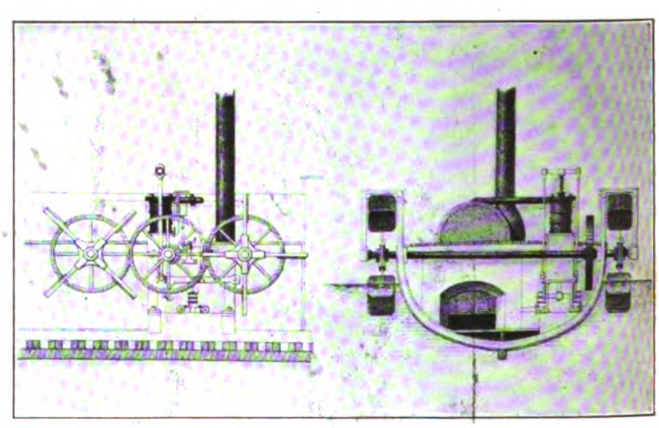
The vessel, herself, was a single hull, with two keels, and had a deep recess formed in the after portion to receive a single paddle-wheel. Separate rudders, linked together, were fitted to the twin sterns. Her over-all length was 56 feet and breadth 18 feet.



LONGITUDINAL SECTION OF THE CHARLOTTE DUNDAS.

With all the elements of signal success, viewed from a more modern standpoint, the vessel proved a failure. Not that she failed to fulfil her designed rôle of a steam-propelled tug, for she successfully towed two loaded vessels, each of 70 tons burden, over 19 miles in 6 hours, against a strong headwind, but because of the over-anxiety of a number of canal proprietors as to damage done to the canal banks by the wash of the propeller.

Like the *Great Eastern* of fifty years later, the *Charlotte Dundas* was in advance of her age, and she ended her career as a derelict in a neighboring creek. Lord Dundas, himself, however, had faith in the new system of propulsion and recommended the notion to the Duke of Bridgewater, who promptly, in 1802, ordered Symington to build eight such boats for the Bridgewater Canal: the unexpected decease of the Duke canceled this promising development.



SECTIONS IN THE MACHINERY SPACE OF THE COMET.

Before leaving the subject of the *Charlotte Dundas* and her designer, it is worthy of remark that the original patent covered the use of side paddles on ordinary-shaped vessels; it also probably originated the idea of an "ice-breaking steamer," by proposing to use steam-driven "beaters or stampers" at the bow of the boat to force a passage in frozen waters. It is also an interesting fact that in July, 1801, Robert Fulton, the American engineer, paid a visit to Symington, took an 8-mile trip in his boat, asked many questions and made notes and sketches of her design.

Although British enterprise had thus so far taken the lead

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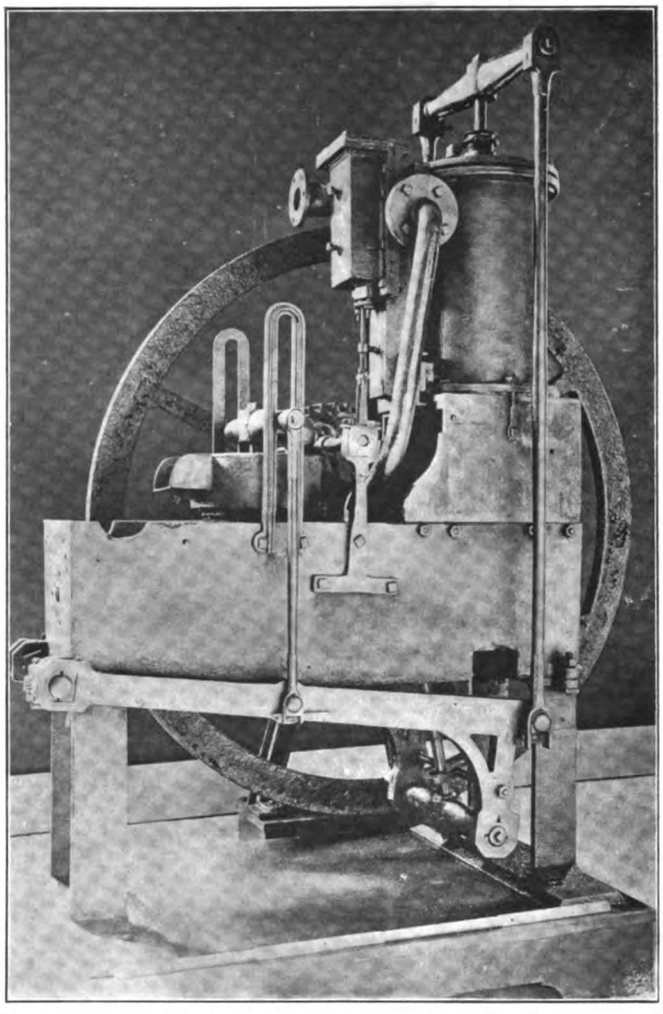
in steamship development, its horizon seemed strictly bounded by the towage tradition, and imagined no possibility of a passenger or general shipping traffic. This important step, however, was successfully made by Messrs. Fulton, Livingston & Stevens, during the next decade, in America. It was largely under this stimulus that commercial steam navigation took permanent shape in Europe by the historic *Comet,* inaugurating a passenger service on the Clyde in January, 1812. The boat was built by Messrs. Wood & Co., at Port Glasgow, for Henry Bell, and carried goods and passengers between Greenock and Glasgow. She was of 30 tons burden, 40 feet long, 10.5 feet broad, and, with only 4 horsepower, averaged a speed of about 6 knots.

Her engines were made by Robertson, of Glasgow, and show a single, upright cylinder 12.5 inches in diameter and 16 inches stroke. This was placed over the working shaft, but drives it by means of two long side rods, which link the cylinder cross-head with two half side-levers joined by an underneath cross-head, which carries a connecting rod acting upwards on an overhanging crank. It should be noted that the fulcrums of these rocking-levers are not at their centers, but at the extreme ends of the arms. This, known as the "grasshopper" type of lever engine, has had considerable vogue for tugboats down to the present day. Uniform motion is given to the crankshaft by a weighted fly-wheel 6 feet in diameter, and the paddle shafts are driven by spur gearing, which reduces the relative speed of paddles by nearly one-half. It is recorded that sometimes, when the small-powered engine showed signs of distress, the passengers would render temporary assistance by turning the fly-wheel. A balanced rocking shaft worked by an eccentric actuates the slide valve. Water tank and condenser form portions of the main engine casting, and inside the tank is the air pump, worked from the side levers. The boiler is externally-fired and set in brickwork. Side paddles and projecting "guards" give the vessel a very modern appearance: originally, two paddles each side, with detached arms, were used, but these were eventually changed to one complete wheel on each side. A lofty funnel served the purpose of a mast, and the vessel is often depicted in contemporary sketches with a large square sail hoisted.

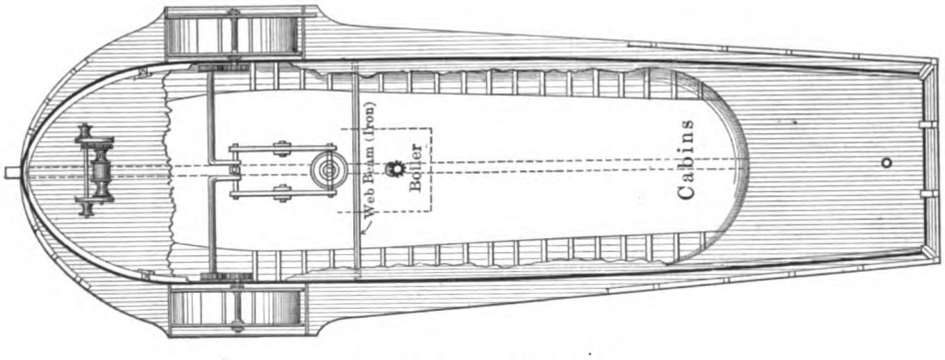
The *Comet* initiated pleasure cruises around the British Isles, and also ran regularly for some time on the River Forth. She was wrecked in 1820.

Once started, the idea of steam river boats grew apace, and within the following four years there were no less than ten paddle steamers plying in the Clyde alone. One of the oldest survivors of these pioneer boats was the *Industry,* built in



ENGINE OF THE COMET, BUILT IN 1812.

with paddles placed well forward, and light "guards" extending the available deck space at the sides. The original engines were probably similar to those of the *Comet,* but were replaced by a new set in 1826; these latter were removed from the old hulk and shown at the Glasgow International Exhibition of 1888, and now have a permanent resting place in Kelvingrove Park, Glasgow. They comprise a single cylin-



DECK PLAN OF INDUSTRY (1814).

1814 by W. Fife, grandfather of the famous yacht designer. After sixty years' service in the Clyde, she was laid up on the river bank, and remained an object of interest to passing visitors as late as 1890. Her deck plan, which we reproduce, is typical of practically all these earlier steamers—a full bow,

der 16 inches in diameter and 24-inch stroke, driving two ordinary side levers. Spur gearing gave the engine a mechanical advantage of about 4:3 in this instance. A certain amount of grinding noise was inevitable in these geared engines, and earned for them the sobriquet of "coffee mills"; they never-

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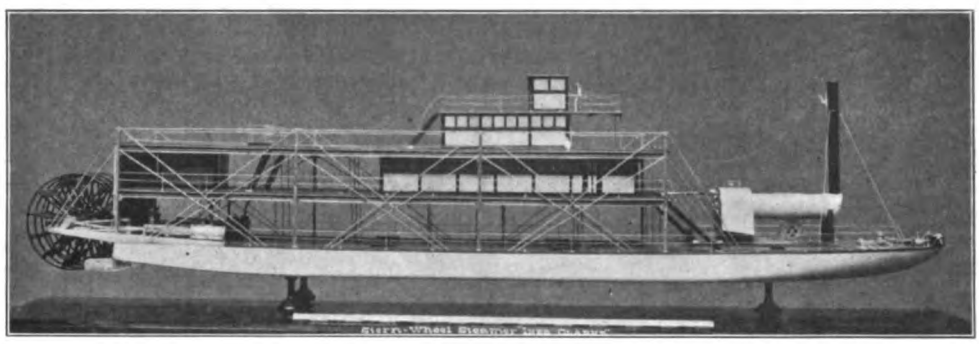
theless were popular for many years, one of the first successful coasting steamers, the *James Watt*, of 100 horsepower, being fitted with them as late as 1822.

The accompanying photograph of the shallow-draft steamer *Inez Clarke*, built by Messrs. Yarrow, in 1879, for South America, is at present the most popular type for inland navigation throughout the world. She obtained a speed of 15 knots on a draft of 15 inches. Some twenty of these craft were constructed for the British military expedition up the Nile in 1885.

As may be readily noted here, we have the conceptions of Hulls and Symington—stern wheel, horizontal engines and multiple rudders—perfected. The modern development in general structural design of the hull is perhaps more marked in character than that of the machinery arrangements.



INEZ CLARKE (1879), THE MODERN DEVELOPMENT OF HULL'S AND SYMINGTON'S CONCEPTION.

THE FIRST STEAM SCREW PROPELLER BOAT.*

The steam screw propellers of Col. John Stevens, in operation on the Hudson River from 1802 to 1806, were the first to be used in steam navigation in any country.

Col. Stevens cannot, however, be considerd the inventor of the screw propeller for the propulsion of vessels, for this device was proposed by the methematician, Daniel Bernouli, in 1752, and it was also described by David Bushnell in 1787, although Bushnell's propeller was operated by hand. The same idea was afterwards suggested by Franklin, Watt and others. Previous to 1802 the screw propeller was twice patented in England, but the propeller was not driven by a steam engine.

The first application of steam to a screw propeller was made by John Stevens on the Hudson in the year 1802. The engines that he tried in 1802, 1803 and 1804 were all non-condensing, and the boilers were all multi-tubular, using high-pressure steam. The propeller was a short, four-bladed screw.

The engine which Col. Stevens used in 1802 was constructed on the rotary principle, to avoid the bad effects of the alternating strokes of engines of the ordinary construction. The cylinder was of brass, about 8 inches in diameter and 4 inches long. It was placed horizontally on the bottom of the boat, and by the alternating pressure of the steam on two sliding wings, an axis passing through its center was made to revolve. This axis, or shaft, passed through the stern of the boat, and on its outer end the propeller was fastened. This constituted the whole of the machinery. Working merely with the elasticity of the steam no condenser or air pump was necessary, and as there were no valves no apparatus was required for opening and closing them.

This engine was installed in a flat-bottom boat 25 feet long and about 5 or 6 feet wide, and a speed of about 4 miles an hour was obtained. Difficulty in keeping the packing of the wings in the cylinder tight for any length of time led Col. Stevens to resort again to the reciprocating engine, and in the following year, 1803, he constructed a small reciprocating engine and installed it in the same boat, driving the shaft by means of bevel gears. A somewhat greater speed was obtained with this than with the rotary engine.

In 1804, Col. Stevens achieved his most successful results with early screw-propeller steamboats. His boat was 25 feet long and 5 feet wide, and was fitted with twin screws, driven by a Watt engine having a cylinder 4½ inches in diameter with a 9-inch stroke. The beam was omitted; the boiler was 2 feet long, 15 inches wide and 12 inches high, containing eighty-one tubes, each 1 inch in diameter. This boat was successfully operated in the Hudson River in May, 1804, obtaining a speed of about 4 miles an hour. Due to accident, it was necessary to replace the boiler, and the next one was constructed with the tubes placed vertically. Under certain conditions it was possible to obtain a speed of 7 or 8 miles an hour with this boat. The illustration shows the original boiler and engine used in this boat, which is now on exhibition at the Stevens Institute, Hoboken, N. J.

Col. Stevens' plan for working twin screws by a single cylinder is the most simple one that could be devised. The reaction of the connecting rods against each other at their junction with the piston rod acts as a parallel motion to keep the rod in alinement, performing the same office as slides. When the screw propeller came into use after a lapse of nearly forty years, this plan of a single cylinder for twin screws was revived, both in America and abroad, being known in France as the Etoile engine. The valves on this twin-screw engine are formed by two-way cocks, a modification of the single-way cocks used by Savery and Newcomen, one cock at each end of the cylinder answering both for the admission and the exhaust of steam. The valve motion was derived from a crank on the inboard end of one of the propeller shafts. This crank worked a rack, the teeth of which meshed into those of the wheels on the plugs of the two-way cocks, this motion being similar to the toothed rack and segment of a wheel used by Watt in one of his first engines to raise his conical valves.

The boiler is one form of the multi-tubular boiler invented by Col. Stevens. It has twenty-eight copper tubes, each 1½ inches in diameter and 18 inches long; fourteen tubes projecting from each side of a rectangular chest. The grate is placed at the end of one set of tubes, and the flame passes around these tubes and then under the chest and around the tubes at the other end to the smokestack.

Some of Col. Stevens' ideas relative to his screw propeller were set forth in an interesting letter to Dr. Robert Hare, of Philadelphia, Pa. In describing the propeller he said that to the extremity of an axis passing nearly in a horizontal direction through the stern of a boat is fixed a number of arms with wings like those of a windmill or smoke-jack. These arms are made capable of ready adjustment, so that the most advantageous obliquity of their angle may be obtained after a few

* Abstract from an article by Francis B. Stevens, in the *Stevens Indicator*, April, 1893

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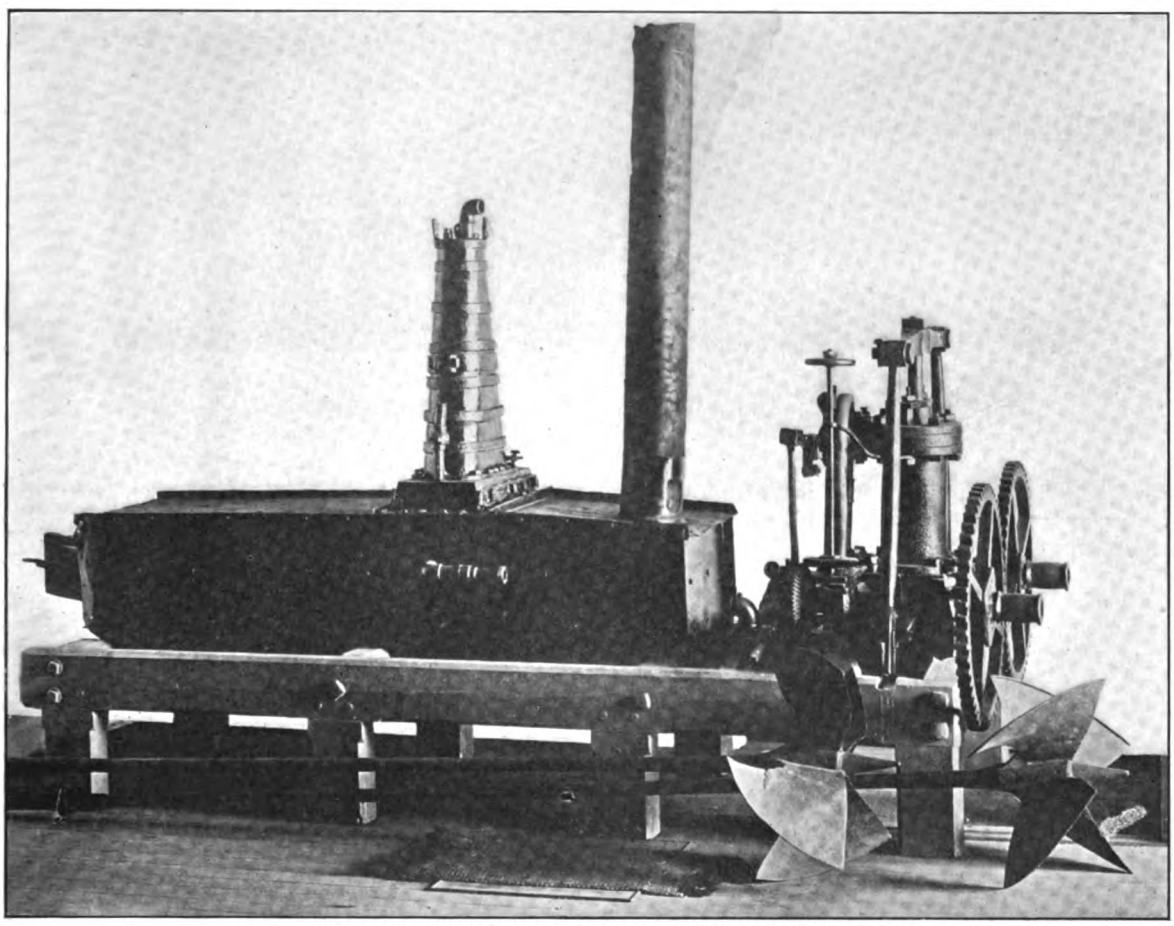
trials. He evidently expected to utilize propellers in shallow-draft boats by increasing the number of the propellers, and, consequently, diminishing their diameter. He stated that it was absolutely necessary to have at least two propellers revolving in opposite directions, to prevent the tendency to rotation which a single wheel gives to the boat. Lack of efficiency in the propeller he accredited partly to the fact that the proper angle of obliquity was not attended to, and to the fact that the wings were made with a flat surface, whereas a certain degree of curvature was necessary.

At the date of the introduction of the screw propeller commercially, the pressure of steam carried on the boilers of condensing engines of the vessels that then navigated the bays and rivers of the Atlantic seaboard averaged about 30 pounds per square inch, while on Western river steamboats the pressure averaged 140 pounds. At the same date the steam pressure on English vessels was virtually the same that Watt had established, namely, 2½ to 3 pounds per square inch. The *Great Western* in 1838 carried that pressure, and the iron screw propeller *Great Britain* in 1864 carried only 5 pounds pressure.

Col. Stevens' attempts to introduce steam navigation by the screw propeller lasted for six years, and were relinquished only one year before the successful application of the paddle-wheel by Fulton. The five distinct improvements he proposed were: First, the short, four-bladed screw propeller. Second, the use of high-pressure steam. Third, the multi-tubular boiler. Fourth, the quick-moving engine, direct connected to the propeller shaft. Fifth, the use of twin screws. None of these improvements were applied to steamships for forty years thereafter, and yet all are elements in the success of ocean navigation at the present day.

An inspection of the rude workmanship of the twin-screw engine, as well as that of the boiler, will explain the reasons for the abandonment by Col. Stevens of his plan of screw propulsion. There were no tools or workmen in America at that date competent to properly construct such machinery, and, therefore, success was impossible. Realizing this, Col. Stevens turned his attention to the paddle-wheel, with its slow-moving engine, and with the boilers then in use carrying steam at pressures of 2 or 3 pounds above the atmosphere. He was engaged in building the *Phoenix* when Robert Fulton arrived from Europe with the engine made for him by Watt in 1806, which, complete in all its details, and, in these respects, far in advance of any engines that could then have been built in this country, achieved success.

The paddle steamboat *Phoenix* was completed a few weeks after Fulton's *Clermont,* but, as she was debarred from navigating the Hudson River by the monopoly given to Fulton by the Legislature of the State of New York, she was sent by sea to Philadelphia, and the *Phoenix* was, therefore, the first steamboat to navigate the ocean.



BOILER, ENGINE AND PROPELLERS OF COL. JOHN STEVENS' FIRST SUCCESSFUL STEAMBOAT.

The first steamship to cross the Atlantic Ocean was the *Savannah,* built in 1818 at New York City by Francis Fickett. The vessel was about 100 feet long, 28 feet beam and 14 feet deep. She was originally constructed as a sailing packet for the New York & Havre Line, but she was purchased by Scarborough & Isaacs, of Savannah, Ga., and fitted with an engine, boiler and paddle-wheels. The engine was of the inclined type, built by Stephen Vail, of Speedwell, N. J., and the boiler was built by Daniel Dod, of Elizabethtown, N. J. The paddle-wheels were 16 feet in diameter, with eight radial buckets on each wheel, so constructed as to be folded up like a fan. The *Savannah's* first trip across the ocean was from Savannah, Ga., to Liverpool. The voyage was accomplished in twenty-seven days, eighty hours of which the vessel was operated under steam.

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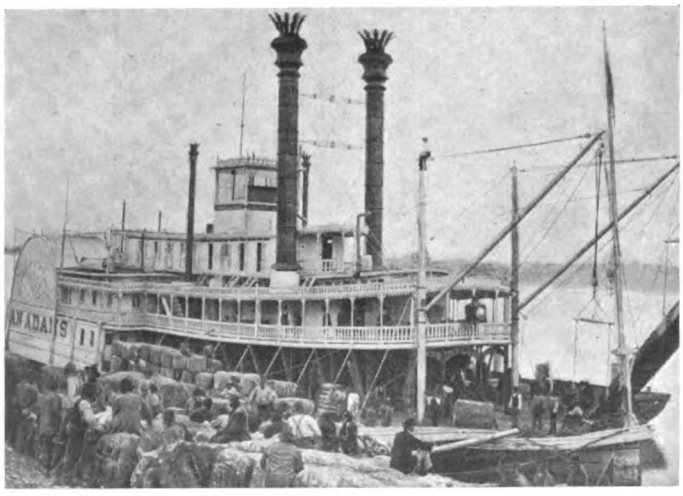
THE DEVELOPMENT OF WESTERN RIVER STEAMBOATS.

BY CAPT. T. M. REES.

The first steamboat to ply on the Western rivers of North America was the *New Orleans,* built at Pittsburg, Pa., by Livingston & Fulton, under the supervision of Nicholas J. Roosevelt, in the year 1811. It was 116 feet long, 20 feet beam, with about 7 feet depth of hold, fittted with a low-pressure engine having a cylinder 34 inches in diameter. Propulsion was by means of side-wheels. There were two cabins, one forward for men and one aft for women. The boat was also fitted with two masts and sails, as, at that time, Fulton thought sails might occasionally be useful. The cost of the boat was about $38,000 (£7,810).

The *New Orleans* made her maiden trip in September, 1811,

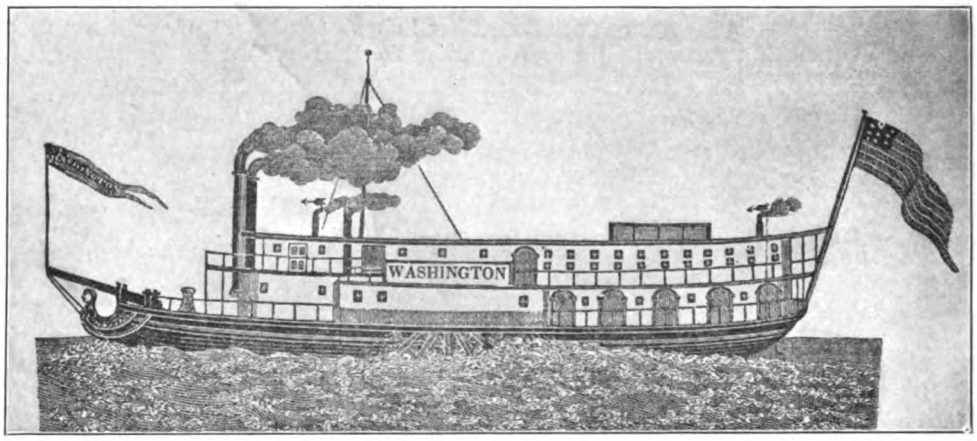


STEAMER DEAN ADAMS, A TYPICAL MISSISSIPPI RIVER BOAT.

and was regularly employed to carry freight and passengers on the route between Natchez and New Orleans. During the night of July 14, 1814, while a few miles above Baton Rouge, La., she grounded on a stump while the water was falling. On endeavoring to free the boat, she sprung a leak and sank.

The next steamboats built for service on Western rivers were the *Comet,* 50 tons, in 1812, which was built from a barge; the *Buffalo,* 250 tons; *Aetna,* 361 tons; *Vesuvius,* 390 tons, and the *Enterprise,* 75 tons, all built in 1814.

The first two-deck steamboat with cabins between the two decks was the *Washington,* 148 feet long, built in 1814, under the supervision of Capt. Henry M. Shreve. She was also the first boat to have boilers with flues on the main deck, and her engines were the first high-pressure engines used. They were also the first engines placed in a horizontal position, giving



STEAMER WASHINGTON, BUILT IN 1814. (FROM AN OLD PRINT.)

vibrations to the "pitman" or connecting rod, besides being the first to use a cut-off cam to secure the benefit of the expansion of the steam.

The hulls of steamboats up to about 1830 were of heavy construction like a sailing vessel. As some of them were fitted with bowsprits and figureheads they had to be handled very cautiously in making landings to avoid damage to themselves or any other boats at the landings. The largest boat built up to 1832 was the *Mohawk,* whose tonnage is given as 555.

The method used on Western river steamboats to supply feed water to the boilers up to 1843 consisted of side pumps, direct connected to the main engines. The main engine shaft was connected to the wheel shaft by a clutch, which could be disconnected by a very strong lever. When the boat was stopped, and it became necessary to supply water to the boiler, the shafts were disengaged by throwing the clutch out of gear, the engines at that time all having large, heavy fly-wheels. This method of supplying water to the boilers was used until 1843, when a horizontal pump, called the "wheel-barrow pump," was made by James Rees, which worked independently from the main engines. The first boiler-feed pump of the type known on Western rivers as the "doctor," was built for the steamer *Missouri.* As is well known, the "doctor" has two cold-water pumps and two hot-water pumps. Water is taken direct from the river through the side of the boat by the cold-water pumps and passed through the heater, where it is heated by the exhaust steam, after which it is passed into the hot-water pumps, where it is acted upon by plungers and forced directly into the boilers. The original "doctor" was operated on one bed-plate with columns and a beam connected to the cylinder, with cross heads, slides and fly-wheel. The second pump of this type was built with a parallel motion, doing away with the slides, and was placed on the steamer *Hibernia II.*

The name "doctor" was given to this pump by engineers at that time because they claimed that it doctored all the ex-

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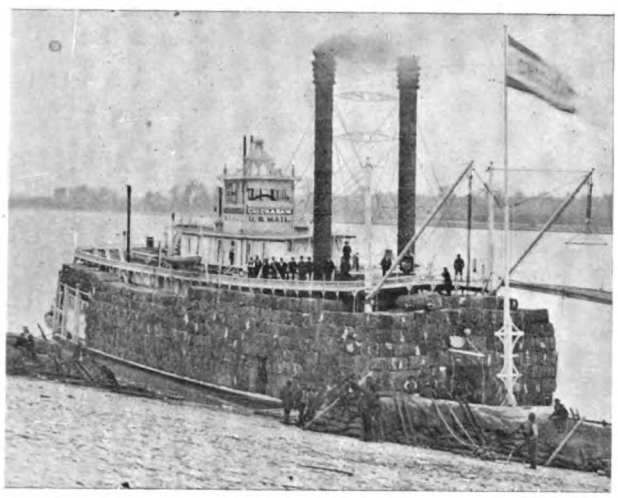
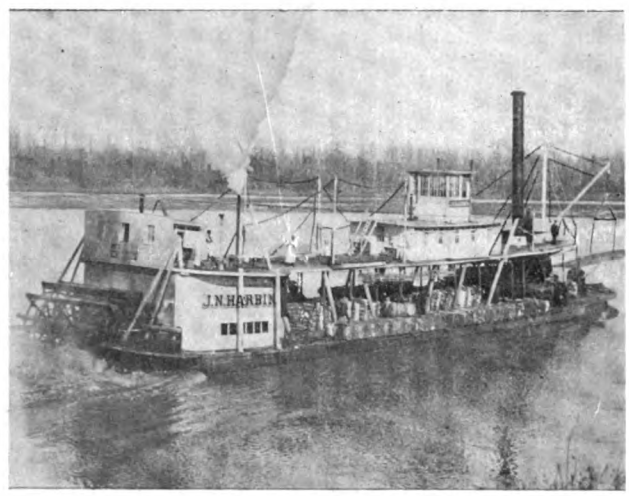
isting evils by giving a steady supply of feed water to the boilers. Under all conditions of steam pressure, and with sandy or muddy water, this pump never failed, and it is known to this day in all parts of the world as one of the very best and safest pumps that can be put on a steamboat for river navigation. The first beam doctors were built by Messrs. Stackhouse & Nelson, engine builders, Pittsburg, Pa.



STEAMER CHICASAW, SHOWING METHOD OF LOADING COTTON.

Another invention was made about this time which showed that Western river boatmen were alive to their best interests. In the year 1843 the steamer *Clipper* was built with two steam cylinders, one high-pressure cylinder exhausting into a low-pressure cylinder, which was separated from the high by a distance piece. From the low-pressure cylinder the steam was exhausted into the heater and then outboard into the air. These engines would be called compound engines at this time, but were then known by Western river men as the Clipper engine, the name being taken from the steamboat on which they were first installed. They were built by Mr. Thomas Litch, engine manufacturer.

In 1854-1855 six steamboats were built which had twin stern wheels, with four engines so connected that the wheels could be operated separately, so that one wheel could be turned ahead while the other was going astern, thus facilitating the handling of the boat. These six boats were the *Challenge,* built in 1854, and the *Adriatic, Alma, William Baird, Aunt Lettie* and *North Star,* built in 1855. It is believed that these were the first boats ever built with twin wheels at the stern. It is now thought by some of the oldest and best steamboat men that by giving the modern Mississippi River boats, capable of carrying 4,000 or 5,000 tons of freight, the length and breadth of beam necessary to return to the twin wheel and four engines, and by making the pair to each wheel cross-compound, and by using balanced rudders, the Mississippi could be navigated safely on the present depth of water in the river without obtaining the 14-foot draft which is so earnestly advocated by the people of the Mississippi Valley.



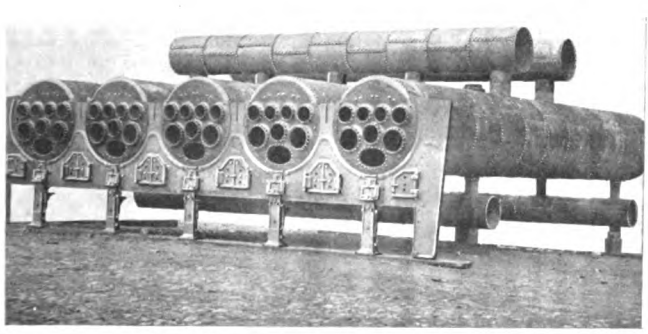
STEAMER J. N. HARBIN, A TYPICAL LIGHT-DRAFT COTTON BOAT.

An idea of the growth and decline of steamboat building on the Western rivers can be obtained from the following record of the number of boats built annually in the Pittsburg district, which includes Brownsville:

Year.	Number of Boats Built Per Year.
1811	1
1812	1
1814	4
1816	1
1817	4
1818	7
1819	8
1823	6
1825	9
1825-1830	12
1830-1835 about	30
1835-1840 "	35
1840-1845 "	40
1845-1850 "	50
1864	80

Since 1864 there has been a steady decline, until now the number seldom reaches more than two or three per year.

The finest packets were run during the years 1845 to 1870. After the latter date the railroads cut in on the passenger traffic, and boats were then built principally for freight capacity. As an example of what freight boats were capable of doing at that time the steamer *Paragon*—built at Pittsburg in 1873, of the following dimensions: Length, 265 feet; beam, 48 feet; engines, 22½ inches diameter, 8 feet stroke; five boilers, length, 26 feet, diameter 40 inches, each having two 15-inch flues; paddle-wheel, diameter 26 feet, length of bucket 28 feet, width of bucket 36 inches—made a trip from Cincinnati to Wheeling, a distance of 370 miles, in forty-seven hours, carrying 1,450 tons of iron ore, with a depth of 6 feet of water in the river. On another occasion she averaged a speed of 10 miles per hour from New Orleans to Cairo, carrying 1,000 tons on a draft of 5 feet forward and 4 feet 9 inches aft.



EXTERNALLY-FIRED FLUE BOILERS USED ON WESTERN RIVER STEAMBOATS.

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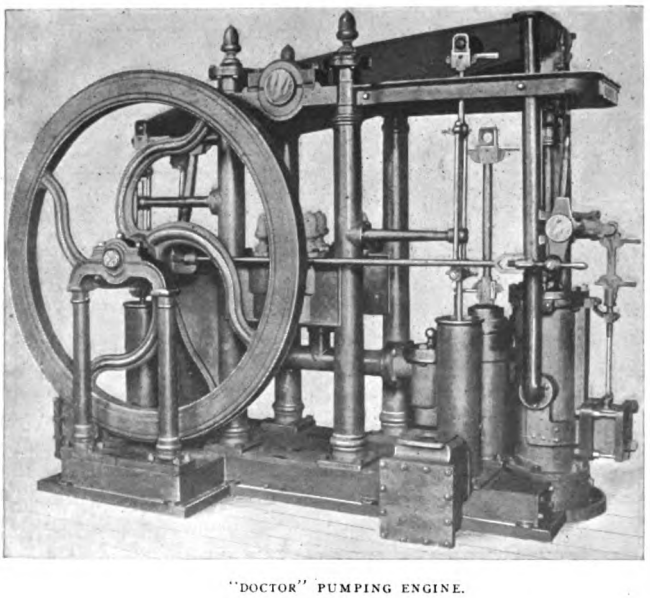
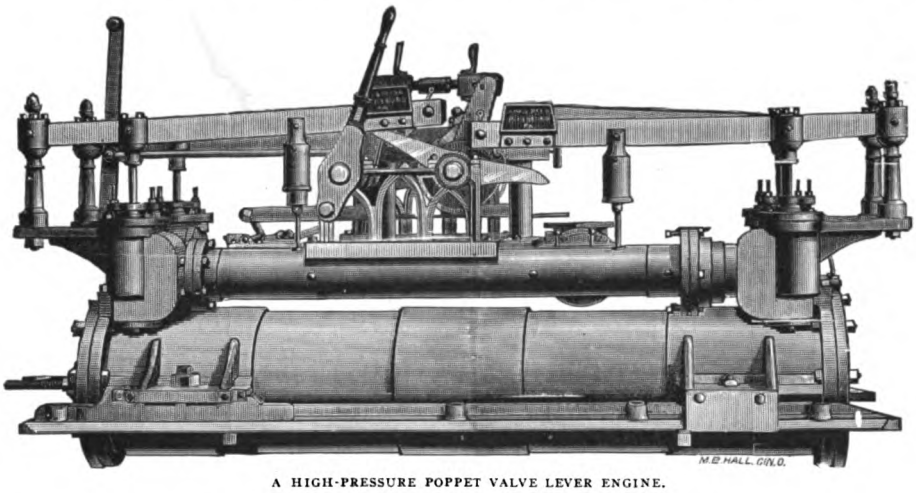
The towing of coal to the lower ports, which commenced about 1850, brought forth another type of boat with barges, which increased the tonnage of boats in Pittsburg, until in 1901 it exceeded in registered and unregistered vessels the tonnage of New York by over 818,000 tons. The capacity of these towboats increased from 50,000 bushels in 1855 to 300,000 bushels in 1900. This increase was made notwithstanding the fact that in recent years the channels in the rivers have been artificially obstructed by bridges, the distance between piers in many cases being less than one-third the width of the river, which was formerly available from bank to bank. The increase is due largely to the experience of the crews, the use of improved machinery and improvements made in the boats and rudders, as it was about this time that the balanced rudder came into use for stern-wheel boats. As ordinarily used, the forward end of the balanced rudder extends under the stern rake of the boat, having about one-third of the rudder forward and two-thirds aft.

The method of towing on the Western rivers is quite different from that used on the Great Lakes, or on the coast or in foreign countries. The barges are all placed forward of the towboat, lapping not more than one-third on the forward end of the boat. When the entire tow is properly made fast, the boat is like a single huge rudder to the tow. This method of towing is now being adopted on other rivers, notably the Yukon.



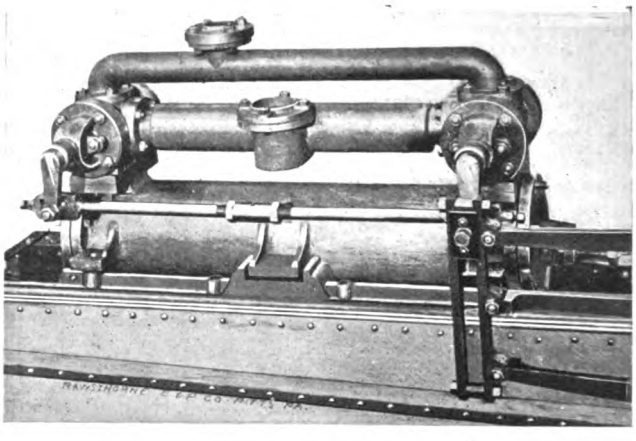
"DOCTOR" PUMPING ENGINE.

Almost all styles of naval architecture have been used in the construction of Western river steamboats. In 1855 a stern-wheel boat was built with the rudder at the bow. A number of boats with a recessed wheel have been built, called "bootjacks"; also twin hulls have been used, joined together to form a catamaran, with the wheel in the center. The tunnel boat and the cone propeller have also been used, but so far no design has excelled the stern-wheel boat for shallow river navigation. In competition with side-wheel boats, where navigation was difficult, the stern-wheel boats entirely drove the side-wheel boats from the trade, particularly in rivers like the Missouri, since with their spars set and the wheel at the stern they were able to pass over bars over which it was impossible to pass with side-wheel boats.



A HIGH-PRESSURE POPPET VALVE LEVER ENGINE.

Shallow draft stern-wheel river steamers of the type developed on the Western rivers are now being used in India,



A HIGH-PRESSURE ROTARY VALVE ENGINE.

Russia, Manchuria, China, Africa and South and Central America. In 1878 the first steel steamboat was built knocked-down for shipment in sections, and the first all-steel hull steamboat built on the Western rivers was the *Chattehooche*, built in 1881.

Among the auxiliaries which are distinctive on Western river steamboats is the steam capstan, working with independent engines, which came into use in the year 1855. This was designed by an engineer named Jack Schaffer, and was built by Robert Rogers, who was also builder of the Rogers hand-capstan. Formerly, when boats were aground, the hand-capstan was turned by the negro deck crew, as most of the

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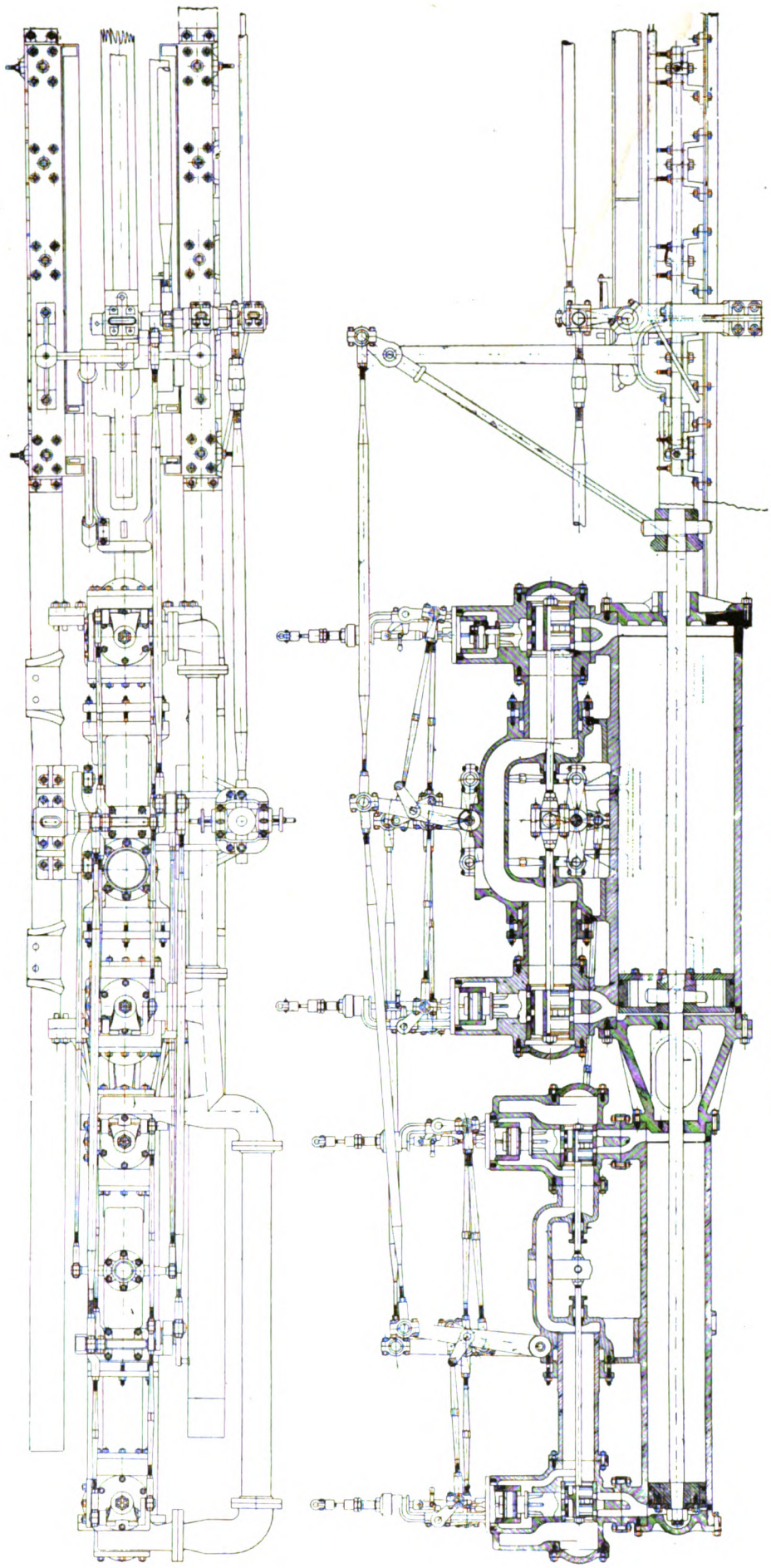

ARRANGEMENT OF TANDEM COMPOUND ENGINES ON STERN WHEEL WESTERN RIVER STEAMBOATS.

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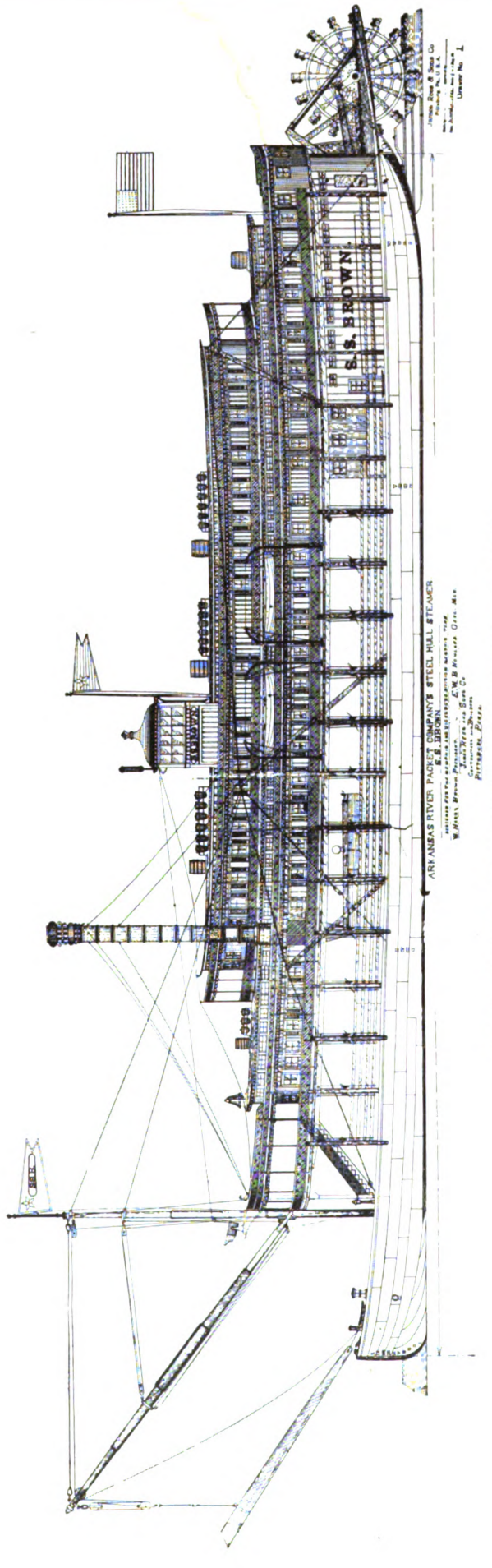


STEEL HULL STEAMER S. S. BROWN, TYPICAL MODERN WESTERN RIVER STEAMBOAT.

deck crews on Western rivers at that time were composed of negroes, and, consequently, when the capstan was connected to an engine the engine was thereafter known as the "nigger" engine, because it did the work of the negro crew in hoisting freight from the hold and turning the capstan. The "nigger" engine was a small, single-cylinder engine, located between the main hatches forward, and was connected to the hoisting drums for each hatch as well as with the capstan. There was a reversing valve on the engine. About the same time a reversing apparatus was applied to the main horizontal engines on stern-wheel boats by James Rees.

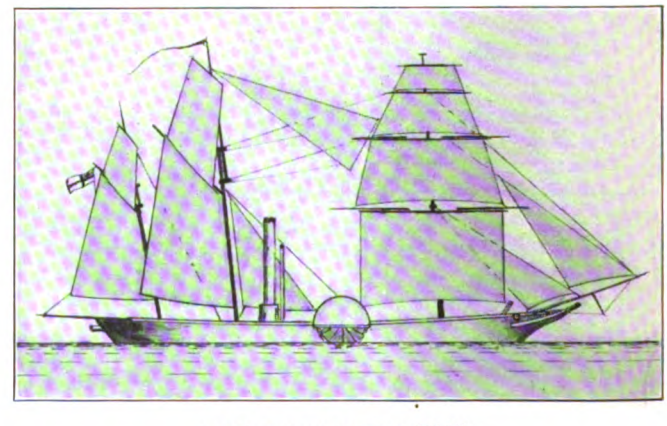
The engines that have been in use for many years past are the horizontal slide valve engine with poppet cut-off; the lever poppet valve engine, the valve being made single, and the relief and double balanced, which developed from the single-side pipe to that of the double, with an expansion joint on engines over 5-foot stroke. Although piston valves in various forms, with cut-offs both inside and outside, have been used, since 1876, however, the double-balanced valve lever engine has been accepted for the best work. Many improvements have been made on this engine. In 1870 James Rees improved it by a patent adjustable or variable cut-off, which did away with the cut-off cam by taking the motion from the cross head. Mr. John Evans, engineer, designed the full-stroke inside cam motion, which was used in the year 1882, and which has since been used by others, until now all modern boats built at Pittsburg do away with any cams whatever on the water-wheel shaft, taking the motion from the cross head or connecting rod. Indicator cards taken from these engines show an almost perfect diagram.

The compound, the cross-compound condensing and non-condensing engines are in use on tow-boats and passenger boats on the rivers.

The boiler which gives the greatest satisfaction is the horizontal tubular boiler, set in an iron casing, with from two to ten flues, as may be desired, although the locomotive, the Scotch, the watertube and almost every conceivable type of boiler has been tried. Up to the present time, however, nothing has been found that fully meets all the requirements of the service as does the horizontal externally-fired tubular boiler.

EARLY WAR STEAMERS.

One of the earliest well-authenticated records of a steam-propelled vessel engaged in actual warfare occurs among the detailed despatches of the First Burmese War, in 1824-'26. Although this was primarily a punitive expedition of the Honorable East India Company to Rangoon, the company's fleet was assisted by British ships and officers during the prin-



STEAM FRIGATE PHŒNIX (1830).

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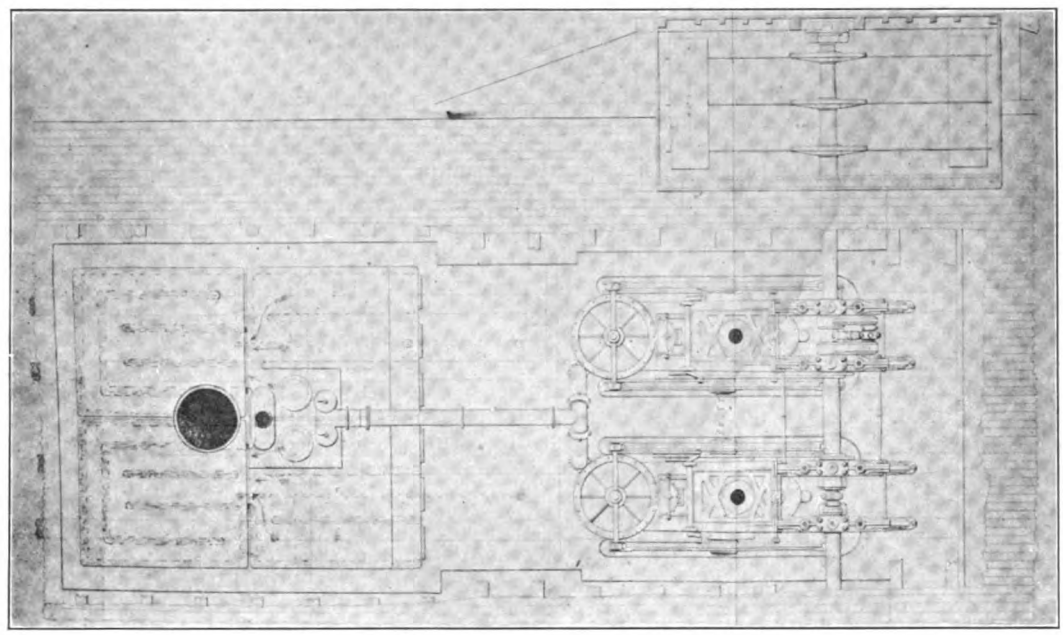


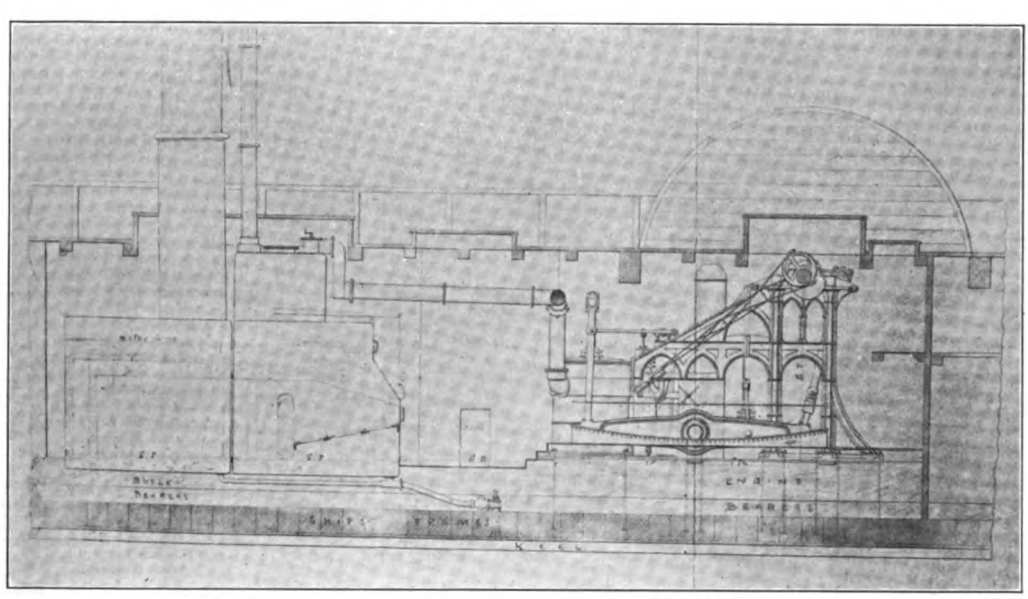
PLAN VIEW OF ENGINES AND BOILERS OF THE PHŒNIX.

cipal operations. Indeed, to Captain Marryatt, the famous novelist, who commanded H. M. sailing frigate *Larne* during the early stages of this campaign, must be awarded the credit, not only of first suggesting, but of successfully adopting steam as an auxiliary to naval tactics. Finding a small paddle steamer, *Diana,* at Calcutta in 1823, he urged her inclusion in the attacking fleet, and this vessel actually took part in the military operations of the following year.

The *Diana* proved an indispensable adjunct to the expedition, and frequent references are made to her use for reconnoitering purposes, transport of troops and towing vessels off the shoals. She is described as "unarmed," although on one occasion she "kept up a well-directed fire of rockets," and on another, "by skilfully decreasing and increasing her steam, he (the captain) wholly baffled the barbarians' calculations of her speed, till he got them within reach of her carronades and musketry." That her machinery was not free from breakdowns, may be inferred from the frequent entries in the log of the *Larne* of sending "carpenters and sailmakers to *Diana.*" It may also be readily surmised that skilled mechanicians were scarce in those days, and one log-entry—after recording an injury to the leg of the *Diana's* engineer—laconically adds "Took steamboat in tow and made all sail."

The origin and dimensions of this noteworthy vessel are somewhat obscure. She is mentioned as drawing 6 feet of water, and of being rather smaller than the *Enterprize,* a vessel 122 feet long by 27 feet broad, and of 470 tons and 120 horsepower. Further, as this latter craft is credited with the first voyage from London to Calcutta under steam, in 1825, it is probable that the *Diana* was built in India about 1822: this surmise is bound up with the fact that the *Snake,* a small river steamer, was really constructed at Bombay, in 1820. Curiously enough, both the *Snake* and *Enterprize* appear to have rendered some services during the Burmese War. These events, however, have no direct bearing upon the attitude of the British Admiralty proper towards steam-propelled war-vessels.

From Viscount Robert Melville, friend of Pitt, and First



LONGITUDINAL SECTION OF THE ENGINES AND BOILERS OF THE PHŒNIX.

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Lord of the Admiralty for many years, came the decision to introduce steam propulsion into the British Navy, and in 1815 the first steam sloop *Congo* was ordered for experimental purposes. When one reflects that the historical Clyde-built *Comet* was scarcely three years old, and that but two small passenger steamers had that year—after much local opposition—commenced to ply on the Thames, this would appear to have been a remarkably progressive step for a navy board still flushed with the triumph of the old order of things at Trafalgar.

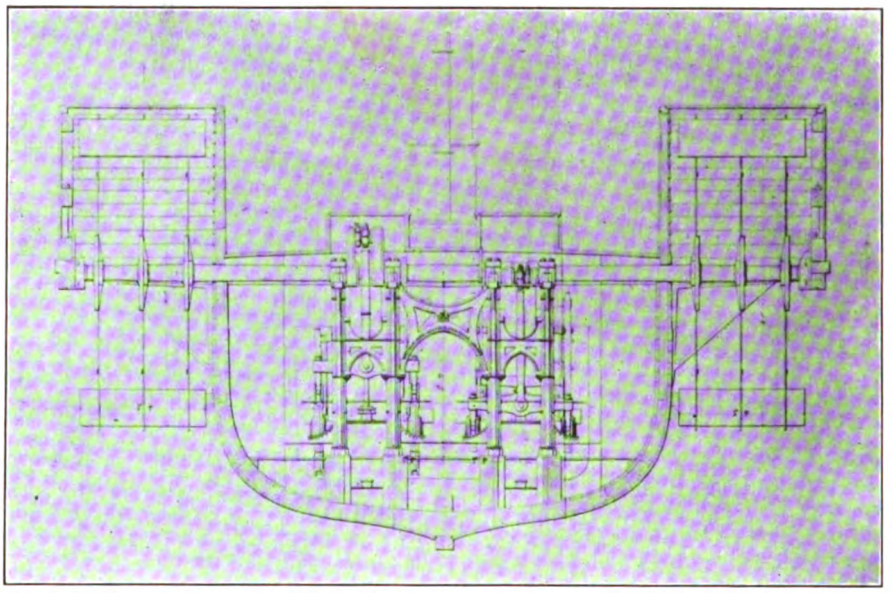
The *Congo* was built, but fitted out as a sailing vessel, while her engines, by Messrs. Boulton & Watt, Birmingham, were sent to Plymouth dockyard for pumping water. This, perhaps, is an unique instance of engineering atavism.

Six years afterwards, largely influenced by the elder Brunel, Lord Melville again essayed the problem and in 1822 had the satisfaction of seeing H. M. S. *Comet*—the first government-built steamer in the navy—ready for sea. She was constructed at Deptford, under the supervision of the celebrated Oliver Lang, and measured 238 tons. Actual drawings of her engines are not available, but they were of the side-lever type of 80 horsepower, with cylinders of 39.5 inches diameter, and stroke 42 inches. Flue boilers were used, and the paddle-wheels were 14 feet in diameter.

During the next few years most of the Admiralty designers tried their 'prentice hands at steamship work. These craft, though built for the navy, carried little or no armament, and were chiefly used for towing large vessels in or out of harbor, for coastal voyages between home dockyards, or for occasional mail service to Gibraltar and Malta. Beyond, however, a progressive increase in dimensions and horsepower, they all had very much in common, and the side-lever engine, made by all the principal contracting firms, was practically universal. As typical of this period we have reproduced details of the hull, boilers and engines of the *Phoenix*, and her sister ships *Rhadamanthus* and *Salamander*, built at various yards during the years 1827-'30.

These "steam frigates" had the following principal dimensions: Length over all, 200 feet; breadth, inside paddles, 32 feet; tonnage, 820. They differed from their predecessors by being well armed. At each end they carried a 6-ton traversing gun of 10 inches caliber and throwing an 84-pound shot—the most powerful gun then in the service: in addition, there were four 18-pounder carronades for use in various other positions. We may therefore fitly describe these vessels as the first real war steamers in the British Navy. Further, the *Phoenix* fully justified her claims to military rank by taking part in the bombardment of St. Jean D'Acre in 1839. She appears to have fired her guns with precision from easily-occupied vantage points, and was used by the Commander-in-Chief (Admiral Stopford) as temporary flag-ship, so as to better superintend the operations. The *Salamander* took part in the second Burmese War of 1851, while the *Rhadamanthus* gained some notoriety as the first steam vessel to make the voyage to the West Indies in May, 1832.

In constructive features the *Phoenix* has a special claim to our notice as being a product of the famous master shipwright, Sir Robert Seppings, who was surveyor of the navy from 1813 to 1832. A glance at the accompanying plan and sections of her hull, in the way of the machinery spaces, will reveal the fact that the shipwrights—the actual wood engineers of those days—did their work thoroughly. The transverse framing here forms a solid wall of closely fitting English oak timbers, varying in thickness from 20 inches at the floors to a molded depth of 6 inches at the top sides; these are secured by treenails and dowels, and further stiffened and bound together by inner and outer wood-skins, each 3 inches thick. Two special deck beams, 16 inches by 24 inches, strengthen the structure abreast of the paddles and shafting, while iron knees are introduced inside and outside in way of the sponsons. Under the engines and boilers are four continuous, longitudinal bearers 14 inches wide and about 3 feet 6 inches deep; these were usually made from hard-grained balks of African oak, and secured to the adjacent ship structure by stout copper bolts clenched at each end.



SECTION THROUGH ENGINE ROOM OF THE PHŒNIX.

The boilers and engines of all three ships were identical, and were constructed by Messrs. Maudslay Sons & Field, London, who were first favorites with the Admiralty for this class of work.

As is well known, the marine boiler did not develop so rapidly as other types, owing to official reluctance to increase pressures, and thereby provide fresh victims for "the Moloch of high-pressure steam."

Iron tank boilers, arranged in two separate units, are here shown. They were fitted with internal, rectangular flues, which gave some circulation to the heated gases before they reached the common uptake. Water spaces were formed at

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the boiler sides and bottom, as well as inside the flue walls and bridges. Stop-cocks were provided for shutting off individual elements when necessary; this arrangement was quite an innovation, most ordinary vessels being without such valve or cock, and thus there was a free communication between the boilers and steam pipe. A contemporary writer upon the subject, however, is impressed with the necessity of all war steamers being provided with such fitting, owing to the difficulty of repairing a boiler if perforated by shot. Water, of course, was drawn directly from the sea, and therefore brine pipes and blowout cocks were necessary for getting rid of the saturated liquid and earthy matter. The need of an external supplementary valve for this and other purposes brought the introduction of the Kingston valve at this period by Mr. Kingston, of Woolwich Dockyard; it consisted of a simple rod and conical valve, worked by hand, and opening outwards; by closing it, any necessary repairs could be safely done to the internal cocks and fittings. They were not universally used at this time, some early steamers having to blow out through their seacocks, thus emptying their boilers, which had to be refilled before steam could again be raised, the vessel, meanwhile, being compelled to sail, drift, or anchor for at least two hours.

Steam pressures varied from 4 to 5 pounds per square inch. Safety valves, steam and water gages were generally fitted. Tubular boilers were adopted in the navy about 1840.

The propelling machinery, in general design, is representative of the side-lever principle in its most popular, practical form. Two independent sets of engines, double-acting and condensing, drove the paddle shaft by means of cranks at right-angles to each other; this gave an easier and more uniform motion, with less liability to absolute breakdown, than the single engine of the earliest boats. A striking feature of the whole design is the heavy character and architectural form of the upper and lower head-stock framing in cast iron—the Gothic style here shown being a favorite one. The two sway-beams or side-levers to each set were 14.25 feet between centers, and were driven by the metallic-packed piston (a rarity at this period) by means of side rods attached to a cylinder cross-head. Rectilinear motion was given to the piston rod by radius bars from each side rod acting through a rocking shaft on the main framing, and a single back link to one of the side-levers.

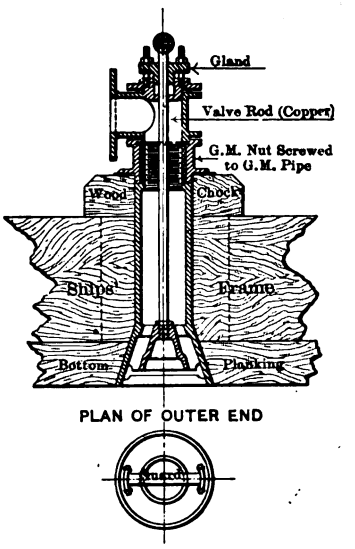
Long D slide valves were used, each actuated by an eccentric rod from the paddle shaft to an arm on the working-gear shaft. The condensers, each placed inside the lower framing, were of the jet type, and supplied by a sea-injection valve similar in character to a Kingston, but provided with a grid and guide rod; it was kept open by a cotter pin. Above the condenser was the "hot well," and above this again the peculiar dome-shaped "air cone," used to prevent any water escaping into the engine room. The condenser was cleared by a vertical single-acting air pump—a foot or clack valve regulating the operation; the pump was driven by side rods from both main levers. For convenience in disconnecting the cranks, when under sail, as well as to reduce the shock to the engines of heavy seas striking the paddles, the crank pins were made in two parts, connected by an intervening piece or driving link—a variation of the drag link: under normal circumstances the paddles could be thrown out of gear in about 5 minutes.

All working parts, except the main levers, were wrought iron. Each set of engines was 110 horsepower. The cylinders were 55.5 inches diameter, with stroke of 60 inches. The paddle-wheels were 20 feet diameter and had fixed floats 8.5 feet by 2.5 feet. With an average of fifteen strokes per minute, a speed of 8 knots was obtained. As far as authentic records of coal consumption exist, they point to 7 to 8 pounds per indicated horsepower.

A scale model of an almost identical set of engines—for H. M. S. *Dee*, 1827—is shown in the machinery section of the Victoria and Albert Museum, South Kensington: it is supposed to have been made by Henry Maudslay himself.

The estimated weight of this type of marine equipment, including engine, boiler and water, and paddles, was 1 ton per horsepower. With the somewhat later direct-acting engines and tubular boilers, this was reduced to 12 hundredweight per horsepower.

Notwithstanding its weight and space occupied, the side-lever engine had the advantages of giving an easy, effective motion to the piston, owing to the great length of connecting rod; the weight of moving parts were so balanced that the piston was in equilibrium and easy to start, and there was less wear and friction in bearings than in most rival types of marine engines. In the mercantile navy this type found even



DETAILS OF THE KINGSTON VALVE.

greater favor than in the Royal Navy: all the early Cunard liners were fitted with them—the finest and largest example, perhaps, being those of the famous *Scotia* (1861), the last paddle-driven Cunarder; they had cylinders 100 inches diameter driving, with a 12-foot stroke, paddle-wheels 40 feet in diameter.

Paddle-driven warships probably reached their highest development in 1845, by the construction of the *Terrible*—one of the most powerful vessels of her time. She measured 1,847 tons, had four (direct-acting) cylinders of 72 inches diameter, developing 800 horsepower, and carried sixteen heavy guns.

In these swaddling days of steam, sails were a necessary auxiliary in all vessels, but it is an interesting fact that it took the Royal Navy just a half-century to grow out of them. As far as possible, in the *Phoenix*, the rig was simplified, and the upper masts and yards were easily lowered on deck when steaming.

Of course, the paddle steamer *per se* was never the *beau ideal* of a fighting machine, and from this date it was rapidly displaced by the screw-propelled ship. Apart from its intrinsic merits, this change made a strong appeal to what one may describe as naval æstheticism. If steam had to be tolerated, how much more ship-shape to place its externals out of sight than to have two ungainly excrescences amidships? That the underwater propeller was less vulnerable was, perhaps, of no greater importance than that it avoided broken sheer lines and permitted once again the long serried rows of gun ports; aye, and even adapted itself readily to the picturesque three-deckers of the "good old times." In 1842, therefore, we find the *Phoenix* transformed: fitted with a 12-foot screw propeller and Penn's vertical, oscillating engines, with which she realized a speed of 8.7 knots. G. P.

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THE FIRST SEA-GOING ARMORCLADS.

La Gloire of France; the Warrior of Great Britain.

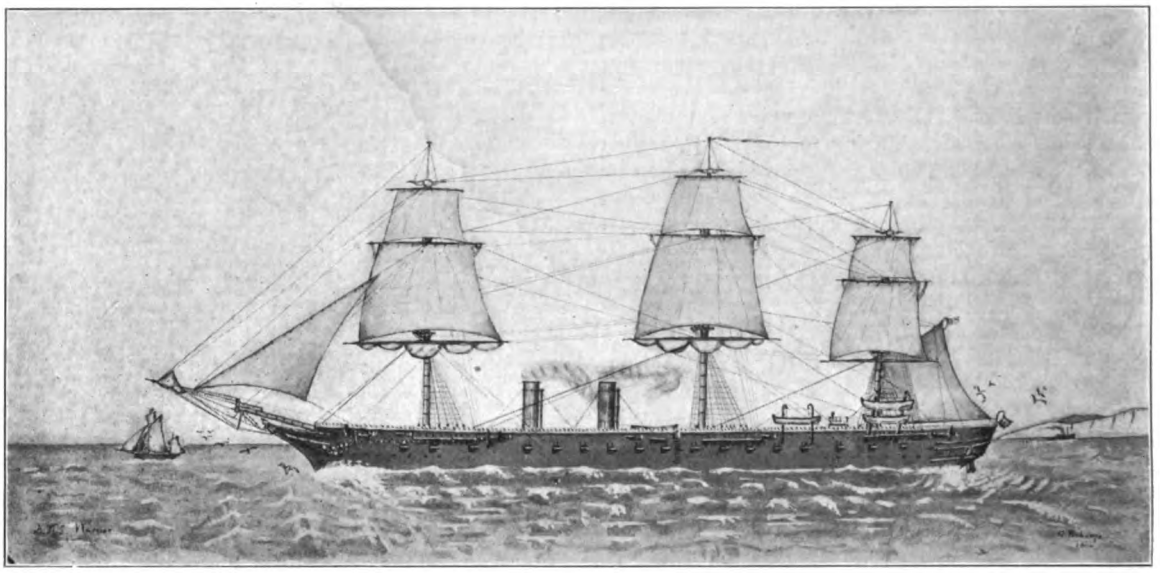
This year marks the jubilee of armorclad ships-of-the-line. That the present type of battleship, with its complex machinery and marvelous capabilities, should have had its inception and development easily within the memory of living men seems scarcely credible. So familiar have become the outlines and attributes of the modern naval fighting machine that one rarely realizes that at the beginning of the Crimean War, in 1854, the combined fleets of Great Britain and France before Sebastopol were entirely wood-built *unarmored* vessels, and many of them guiltless of the means of paddle or screw propulsion. Indeed, so comparatively recent has been this constructive revolution that one of the original parents of iron-clad navies—the *Warrior*—is still in existence and doing good and singularly appropriate service in the British Navy as mothership to torpedo craft.

Incidentally this raises the interesting question of the origin or parentage of the modern battleship. If this were ever the subject of academic discussion, it would be fairly safe to claim it as of Anglo-American extraction, with French god-parents. The bases of such a claim may be thus briefly stated: Stripped of its multifarious, not to say unnecessary, fittings, the first class battleship of to-day reveals an armored sea-going vessel built of steel, and carrying its main armament on movable turntables. These essential factors in the new naval *materiel* all came permanently into being during the momentous period of 1858-62. The practicability of the turret or revolving gun-platform was demonstrated with dramatic completeness by the American *Monitor*, and the suitability of the metal hull for all naval and military purposes by the British *Warrior*, the French having, meanwhile, solved the question of the sea-worthiness of armorplated vessels by their ocean-going, wood-built ironclads. The story of the phenomenal design, construction and success of the *Monitor* is well known, and it is therefore rather with the earliest developments of the modern warship in France and Great Britain that we propose to deal.

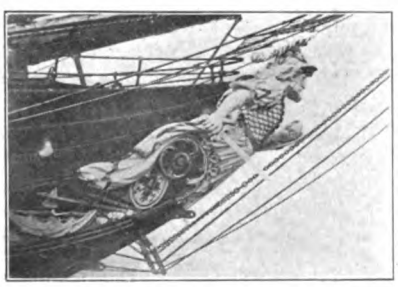
To obtain a clear conception of the need for any such revolutionary changes in warship design, we must revert to the period when the explosive shell made its début as a destructive agent in naval warfare. At Sinope, in 1853, a Turkish squadron of twelve ships was attacked by shell fire from an inferior Russian fleet; and *a single Turkish ship alone* escaped to tell the tragic tale of conflagration and destruction. This gave food for thought to all the important Powers. Were not their magnificent fleets of wooden line-of-battleships and frigates all liable to the same fate? Such vessels could be relied upon to stand severe battering with orthodox missiles, as many a long, hard-fought engagement would bear witness; but against these bursting fireballs—scattering death among the gunners and blasting and burning with their fierce breath the stoutest oak timbers—they could hope to offer no prolonged resistance. Obviously, something was necessary to give the hitherto invincible wooden walls adequate protection against this new-found form of attack. All felt that a change in the existing order of things was impending—was imperative—but few dared to hasten the inevitable.

Undoubtedly the earliest attempt to put into practical form the current speculative theories upon this vital question was made by Napoleon III. In 1855 he built several small barge-like vessels, clothed them with thick iron plates and sent them into the forefront of battle against the Russian forts at Kinburn. To the surprise of an onlooking world they survived the fiery ordeal comparatively unscathed; both shot and shell fell harmlessly upon their protected sides.

So convinced was the British Government of the value of this experiment that they rapidly built a number of similar small batteries. But the ultimate logic of these significant events had yet to be reached. Light draft batteries, with small crews, little stability, and no maneuvering qualities could never form the first fighting line of a great sea power.



H. M. S. WARRIOR, THE FIRST IRON-BUILT SEAGOING ARMORCLAD IN THE WORLD.



FIGUREHEAD OF H. M. S. WARRIOR.

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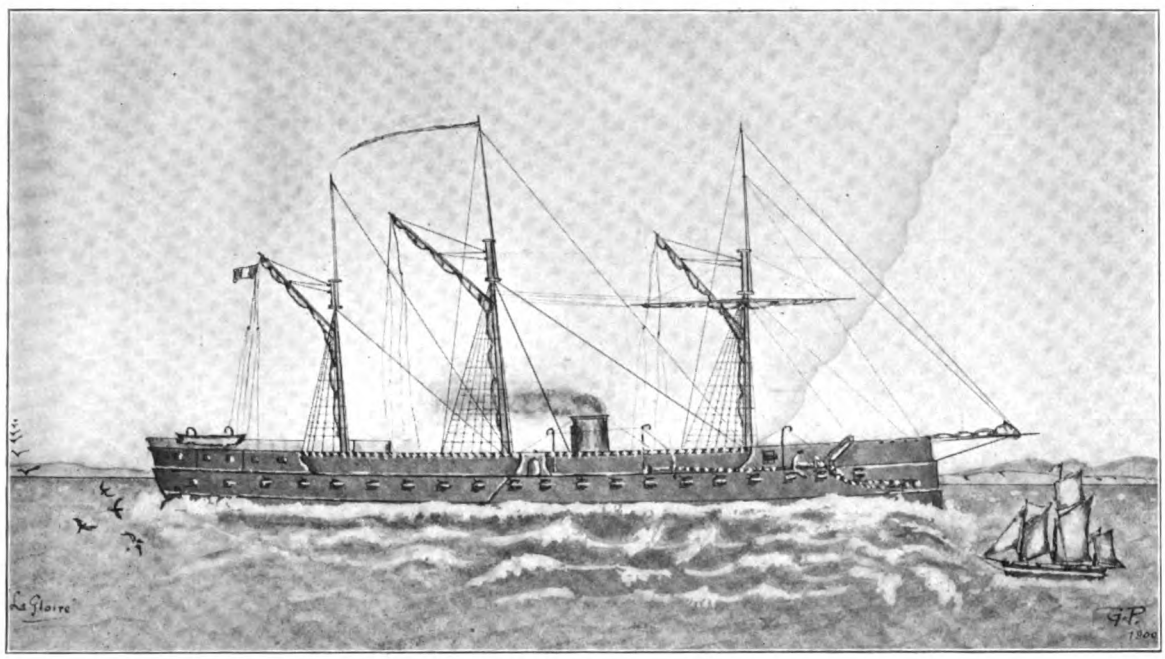


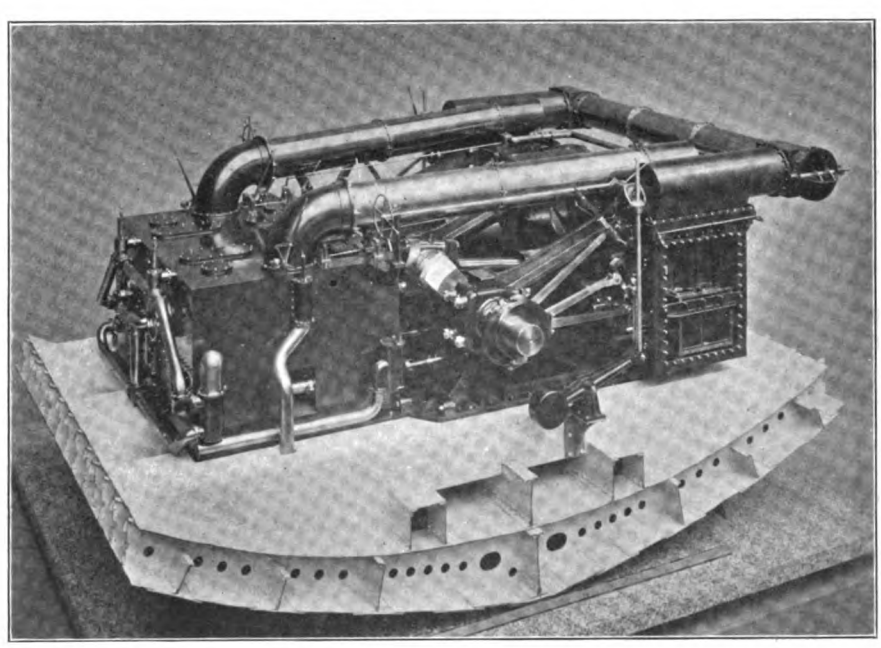
LA GLOIRE, THE FIRST FRENCH SEAGOING ARMORCLAD.

What then? Why—if mobility, sea-worthiness, coal-carrying capacity, fast-steaming qualities were as necessary as the powers of defense and offense—then the warship of the future must be a large sea-going ironclad!

It required little imagination to arrive at this conclusion, but it meant no small effort to the proud possessors of large, splendidly-equipped wooden fleets to fully realize its suggestiveness. Like a troublous nightmare, the problem of naval efficiency sat heavily upon the Great Powers.

Again the initiative came from across the Channel. M. Dupuy de Lôme, the eminent French naval architect and engineer, suggested the transformation of existing two and three-decked ships into single-decked armor clads by the simple expedient of omitting in the new design the heavy upper decks and substituting on the dwarfed and lightened hull a breastwork of thick plates.

On these lines, therefore, was constructed at Toulon in 1858-'59, the famous *La Gloire,* the first sea-going ironclad. As many existing accounts of the genesis of this noteworthy vessel are either vague or misleading, it will be well to give some authentic details on this matter.



TYPE OF ENGINE USED IN H. M. S. WARRIOR.

To make one essential feature clear, *La Gloire* was an entirely new ship, and not a converted three-decker. M. de Lôme, with ten years' experience at the French Bureau of Construction, set about his task of heading a naval revolution with admirable caution, and with the least possible disturbance of existing traditions.

One of the most successful types of screw war vessel in the

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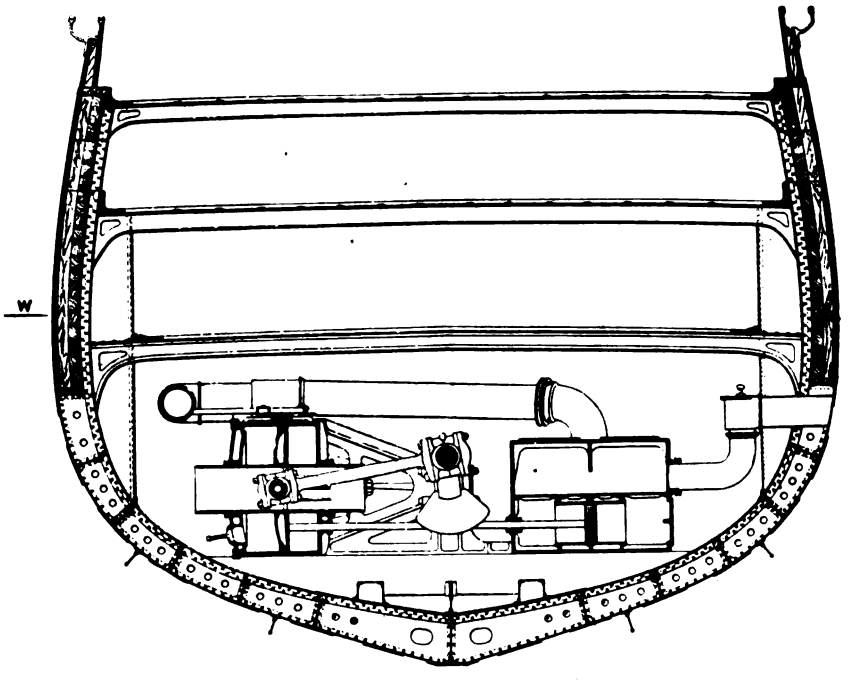
French Navy at this time was a 91-gun class, known as the *Napoleon* or *Algèsiras* class, built in 1850-'55. Tested under steam and sail in all conditions of service, they had proved highly satisfactory. Assuming this safe type, therefore, as his criterion, and furnished with all necessary data as to their



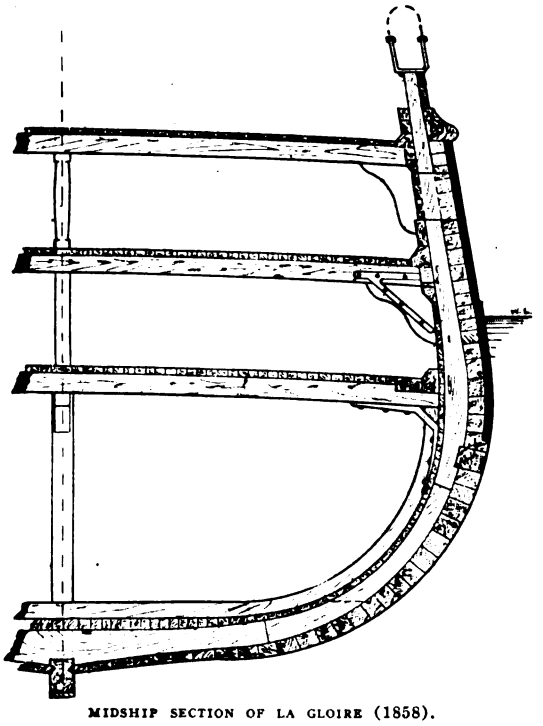
MIDSHIP SECTION OF THE WARRIOR CLASS, SHOWING LOCATION OF THE ENGINES.

performances at sea, M. de Lôme carefully made—on paper—the calculated readjustments of weights to produce a new armored design, with all the established virtues of the old unarmored one. He found that by the removal of the two upper decks and their guns, plus a proportionate reduction in crew and stores that would naturally follow, he could save about 800 tons, or, approximately, the total weight of armor required for the protection of a frigate or one-decked design having the same displacement as the model ship. From plans prepared on these assumptions *La Gloire* was actually built.

As the normal hull-framing of the later types of wooden men-of-war was specially arranged to support heavy top-side weights, in the form of several tiers of heavy-gunned decks, it was fairly well fitted to carry this freshly-disposed load of external armor without undue structural straining. Few additions were therefore made in the new design to the massive bridge-like combination of vertical, horizontal and diagonal oak timbers with overlying riders, which formed the lower middle structure of the pattern type.

The upper works were built into a solid wall of timber in order to make a stout "backing" for the iron plates. A simple upright stem was substituted for the familiar overhanging cut-water, and some modification was made in the shape of stern to avoid extreme curvature in fitting the plates; these, with a slight addition to the total length of vessel, were the chief structural changes embodied in the new ship.

The cuirass, or belt of armor, extended completely around the hull, with a total width of 18 feet, of which 6 feet were below the waterline. It varied in thickness from 4 inches to 4.75 inches, sufficient to meet the attack of the British 68-pounder gun, the most powerful gun then afloat, and to thus give protection to thirty-four of her own main armament of 46-54-pounder guns. (It is a striking commentary on the half-century's progress in naval artillery to note that the modern 12-inch gun, or 850-pounder, is capable of penetrating 50 inches of wrought iron armor.) This armor plating consisted of *hammered* iron, in pieces 6 to 12 feet long and 2 to 3 feet wide, arranged brick-fashion on the side; the idea of *rolled* plates came from England at a somewhat later date. Each plate was secured in position by twenty to thirty galvanized wood-threaded bolts or screws 18 inches long and 1.5



MIDSHIP SECTION OF LA GLOIRE (1858).

inches diameter, with countersunk heads; these were considered preferable to nut and screw bolts under the jarring effects of shot attack.

A special feature of the upper deck of the new ship was an armored redoubt or conning tower. This formed part of the navigating bridge at the after end, and gave protection to the steering wheels, and to the responsible officers during action.

Following the usual practice in warships of this period, the

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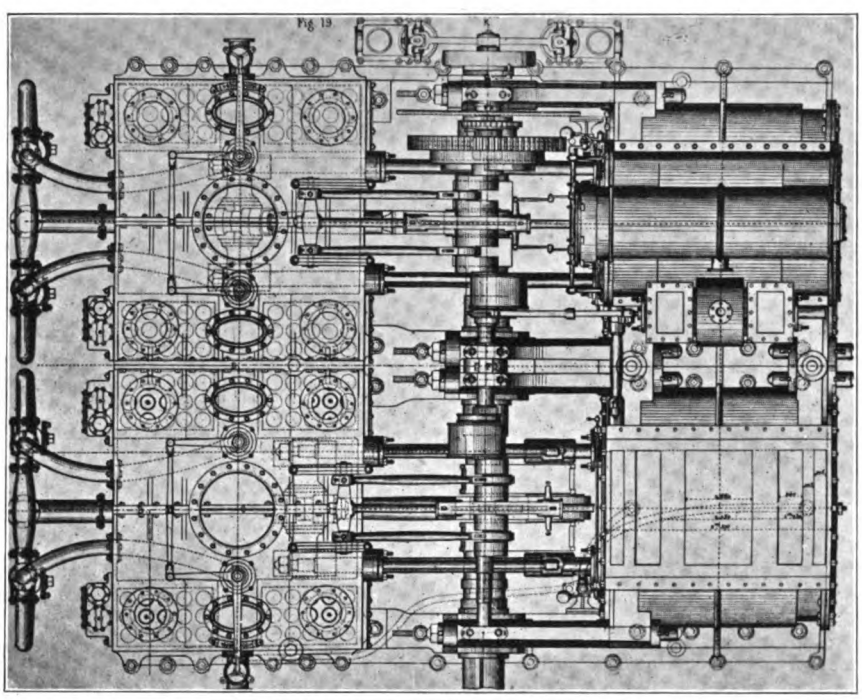
propelling engines were placed as low as possible in the ship's hold, as a safeguard from gun fire, and were arranged with remarkable compactness in the cramped spaces on each side of the propelling shaft. (It was not until nearly twenty years afterwards, when the armored or turtle-back deck at the region of the waterline gave special protection to the ship's vitals that the present vertical types of engines came into favor.) To meet the current requirements of height and space, therefore, the cylinders of all engines were horizontal, and either the "crank" or "return connecting rod" principle adopted to obtain the necessary length of stroke. It is interesting to compare three typical methods used by representative engineers to meet these demands. It will be seen by the *Warrior's* engines, Messrs. Penn made a passage for the piston and connecting rod actually inside the circumference of the steam cylinder. Messrs. Napier found a cooler place for the purpose, inside air pumps of large diameter; while M. de Lôme favored a recess or tunnel, formed inside the condenser area. These latter engines were of the return connecting-rod type that the designer had already popularized in the French Navy, and which eventually superseded all other forms; with slight modifications they continued in general use as late as 1885.



PLAN VIEW OF THE ENGINES OF LA GLOIRE (1858).

The two steam-jacketed horizontal cylinders were placed on the starboard side of the main shafting, while the condensers, of the jet type, were arranged on the port side. Solid, transverse timber-bearers, varying from 12 to 24 inches in thickness, formed a continuous engine bed some 20 feet in length. Each cylinder had a diameter of 81 inches and a stroke of 49.5 inches, the two cranks being set at right angles: on the underside of the cylinders were relief valves which automatically discharged accumulated water into the condensers at each stroke of the pistons—a precaution not then adopted by British engineers. Two piston rods were fitted to each cylinder, joined by a diagonal cross-head, working in top and bottom slides within the condenser recess. Distribution of steam was effected by long D-valves placed on top of the cylinders and operated by a valve crankshaft; this was arranged directly over the main shaft, from which it was driven by two equal spur wheels: motion was given to each valve by twin connecting rods from the valve shaft joined to a valve rod crosshead, which was carried in slides fixed to the top of the condensers.

Steam was supplied at 25 pounds per square inch by eight return flue boilers, arranged in sets of four on each side of the center line; there were four furnaces to each boiler.

A four-bladed propeller, 17 feet in diameter, was used: on trial with fifty-one revolutions per minute and 2,537 indicated horsepower a speed of 13 knots was attained.

At sea, the behavior of the experimental ironclad quite fulfilled the expectations of her designer; in speed, handiness and weatherly qualities she was at least the equal of her unarmored consorts. A fleet of similar vessels was at once projected and built, and it is a curious historical fact that, notwithstanding the rapid adoption of iron-built and armored warships by most other nations after 1860, the French retained confidence in their wood-built ironclads until 1872, when about thirty of such vessels had been added to their fleet.

Meanwhile, before the trials of *La Gloire* had demonstrated the practical success of so powerful a battle unit, Great Britain took alarm at the significant naval policy of her hereditary rival. As far back as 1855, English designers had submitted plans for new armored vessels, but divided counsels at the Admiralty had militated against their adoption. However, this formidable menace to British sovereignty of the seas was a trumpet-call to arms—an appeal for immediate and united action. From the dusty archives of Whitehall, from the secret lockers of the great engineering and shipbuilding firms, came a ready response. For a time, at least, the period of debate and vacillation had passed, and a unanimous cabinet sought and readily obtained the advice of practical men both outside as well as inside the government service. So prompt and so ungrudging were their labors that within a few months of the birth of the French prodigy a British rival was announced, larger—stronger—faster, and more revolutionary in character!

At Blackwall, in May, 1859, was laid down H. M. S. *Warrior*—the most novel, most powerful, speediest man-of-war of her time. Some idea of the boldness and magnitude of the step taken by the British Admiralty may be gathered from the following summary:

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The *Warrior* was half as large again as her French contemporary, was a knot faster, and carried her battery of the heaviest guns afloat 3 feet higher than *La Gloire*. But far above these substantial claims to superiority was the unique fact that the *Warrior* was structurally built of iron! The massive wooden ribs and planking of *La Gloire* had been outmatched in strength, durability and lightness by a combination of metal plates and frames which, still further, possessed the inestimable virtue of incombustibility. Her graceful sheer, clipper-bow and general yacht-like lines were the admiration of even her critics, and were a striking contrast to the heavy, ungainly aspect of *La Gloire*.

But this triumph of British enterprise and skill was not originated or consummated without some opposition and difficulty. Serious obstacles were forever confronting the Parliamentary advocate, as well as the technical adviser. It required as much finesse and tact to pilot each untried revolutionary proposal through a House of widely divergent opinions as indeed it required engineering courage and resource to rapidly construct an unprecedented design in an entirely new material. The ultimate issue, therefore, was as much due to the untiring zeal of the Admiralty chiefs—Sir John Pakington and Sir Baldwin Walker—as to the practical skill of the Chief Constructor (Isaac Watts) and his colleague John Scott Russell, of *Great Eastern* fame.

One can scarcely realize, except by close study of contemporary records, the strong widespread prejudice against the use of iron for war-vessels that existed at this period. Iron had been successfully adopted in the construction of merchant ships and transports for over twenty years previously, but the idea of adopting such an experimental basis in the building of our first line of defense was, to many, fraught with grave national risks.

All tradition and long precedent was against it! The staunch old wooden walls had, from the time of Queen Elizabeth, worthily upheld the prestige of Englishmen upon the sea, and—was it altogether wise to introduce an entirely strange and new fighting machine? Further, the existing navy had been the gradual, almost imperceptible, growth of centuries. Modifications had slowly crept in as regards size and form of various classes, but the general features of the ship of 1850 were practically the same as of those which defeated the Spanish Armada in 1588. Now, the well-tried oaken timbers were to be hastily displaced by a new material, which, furthermore, had not escaped unscathed from the ordeal of several practical tests under gun fire.

The launching and rapid fitting-out of *La Gloire*, however, influenced many waverers. New iron vessels were laid down, and plans for larger and more costly units approved. At the same time the work on the *Warrior* was pushed forward, and just before the close of 1860, the hull was ready to leave the slipway of the Thames Yard Shipbuilding Company, Ltd. (now Thames Ltd.), Blackwall; her phenomenal launching weight of 4,350 tons made this event of special interest to shipbuilders and engineers throughout the kingdom. But the interest awakened by the building of the *Warrior* was world-wide, and more notables were to be seen at Thames Yard and Victoria Docks than, perhaps, ever visited a private establishment before or since. Royalties, Ambassadors, Attachés came from all the Courts of Europe, and, as a result, the Thames Yard ultimately received orders for the construction of many of the earliest iron-built armor-clads possessed by Spain, Turkey, Russia, Germany, etc.

In August, 1861, the *Warrior* was handed over to the government to complete her sea-equipment and prepare for trials.

As may be seen by the cross-section of this remarkable vessel, her general structural features bear a close resemblance to those of the modern battleship. There is a combination of longitudinal and transverse girder frames, the former being continuous throughout the greater part of the vessel's length, and spaced as shown, while the latter are worked intercostally and spaced 44 inches apart. It will be noted that the transverse frames extend slightly above the longitudinal, and are tied together by double angle-bars, which take the inner curvature of the hull: this was a precautionary detail of the early iron worker, which was soon discontinued as an element of transverse strength. The simple "bracket" plate, as used at present, was first adopted in the *Bellerophon* of 1865. At the extremities of the *Warrior*, the transverse frames were spaced 22 inches apart and formed of stout angle-bars (and reverse bars). The shell plating varied from 1⅛ inches to ½ inch in thickness. The cellular double bottom was limited in breadth to the first longitudinals on each side, and in length, to the machinery spaces. Watertight bulkheads and decks subdivided the hull at all important positions. Stem and stern posts were heavy iron forgings.

Box girders, fitted both fore-and-aft and athwartship, carried the weight of the propelling engines. These were of the ingenious "trunk" type, popularized by Messrs. John Penn & Son, of Greenwich. Their general character and arrangement is shown by our illustrations. The two cylinders were each 112 inches diameter; the largest ever cast for marine purposes at this time. To obtain a length of stroke of 48 inches in strictly limited space, the piston rods and guides were abolished, and light, sliding trunks, carrying the inner ends of the connecting rods and passing completely through the cylinders, were substituted. Occasional leakage of glands, and losses, due to the alternate heating and cooling of the trunk surfaces, appear to have been the only drawbacks to this excellent type of engine, which continued to be fitted to large warships as late as 1876. Steam at 22 pounds per square inch was supplied by ten tubular boilers, each fitted with four furnaces. Under steam trials in 1861, with a 24-5 foot Griffiths' screw, a speed of 14.35 knots was obtained, the engines making about fifty revolutions per minute.

Unlike *La Gloire*, the *Warrior* was not armor-clad from end to end. Her 4.5-inch iron belt, with 18 inches of wood-backing, extended over only 213 feet of her amidship length, an efficient termination to these armored sides, however, being given by armor screens or bulkheads across the ship, which afforded protection from raking gun-fire. The unarmored ends of the vessel were safeguarded by cellular subdivision.

Another marked difference in the designs of the two vessels was the treatment of sail propulsion. The *Warrior* was fully ship-rigged, and under sail-power alone proved almost as fast as the "crack" wooden frigates in the British Navy. A lifting screw propeller and a telescopic funnel provided for sailing cruises. Under both steam and sail power the vessel attained a speed of over 17 knots, making her by far the fastest warship afloat. In *La Gloire*, sails were considered chiefly as an auxiliary, a light schooner rig being adopted. When using sail alone, a short length of main shafting was uncoupled, and the propeller revolved idly in the water.

It is interesting to note that with the *Warrior* class ended the picturesque practice of fitting elaborately-carved figure-heads in the British Navy.

The more distinctive particulars of the rival vessels are given in the following comparative table:

	La Gloire.	Warrior.
Length (waterline)	255 feet.	380 feet.
Breadth	55 7 feet.	58 feet.
Draft, mean	25 5 feet.	26 feet.
Displacement	5,700 tons.	9,000 tons.
Armament (original)	46 (54 pounders).	40 (68 pounders).
Guns, above waterline	6 feet.	9 feet.
Armor	4.75 inches (complete).	4.5 inches (partial).
Indicated horsepower	2,500	5,600
Speed	13 knots.	14 35 knots.
Weight of machinery	830 tons.	920 tons.
Cost of machinery	£50,000 ($243,325)	£75,000 ($364,990)
Cost of hull	£145,000 ($705,643)	£300,000 ($1,459,950)

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These also afford opportunities for some instructive parallels with warships of to-day. A good impression of the relative size and appearance of the two ships is given by our illustrations, drawn to the same scale.

On the grounds of economy and expediency the French had every reason to be satisfied with their policy: vessels of *La Gloire* type were better maneuvered and armored, and could be produced more cheaply and rapidly than those of the *Warrior* type: it was, in fact, an ideal *transition* policy, and an excellent method of using up old *material.* It, indeed, had many adherents in Great Britain. Although vessels similar to the *Warrior* continued to be built, a number of the old wooden line-of-battleships were converted into ironclads. But, perhaps, the most amazing chapter of this vacillating, if epoch-marking, period, was the action of the British Government in purchasing huge stores of timber and continuing to build wooden warships that were already marked down for the shipbreaker by their own policy of iron construction.

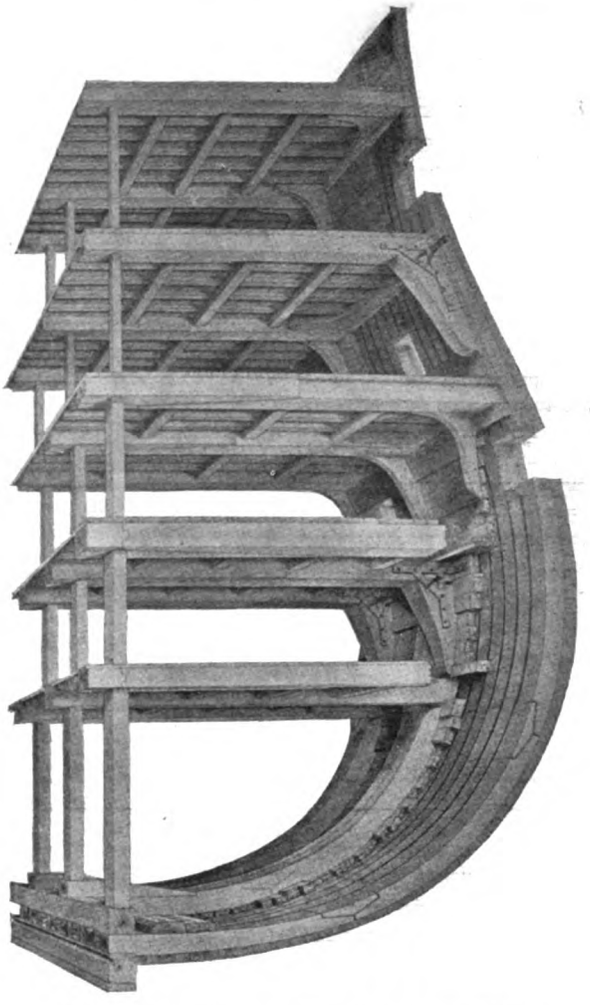
Of the reputed progenitors of the modern battleship then we have now only the *Warrior* left to us. Owing to recent alterations, it is too late to save the historic vessel in its entirety, but it is to be hoped that when the old craft has discharged her maternal duties unto decrepitude, something may be spared—something of her machinery or hull found worthy of national preservation, so as to hand down to posterity; some living, lasting memorial of a red-letter period in marine construction and engineering. P.

NELSON'S FLAGSHIP VICTORY.

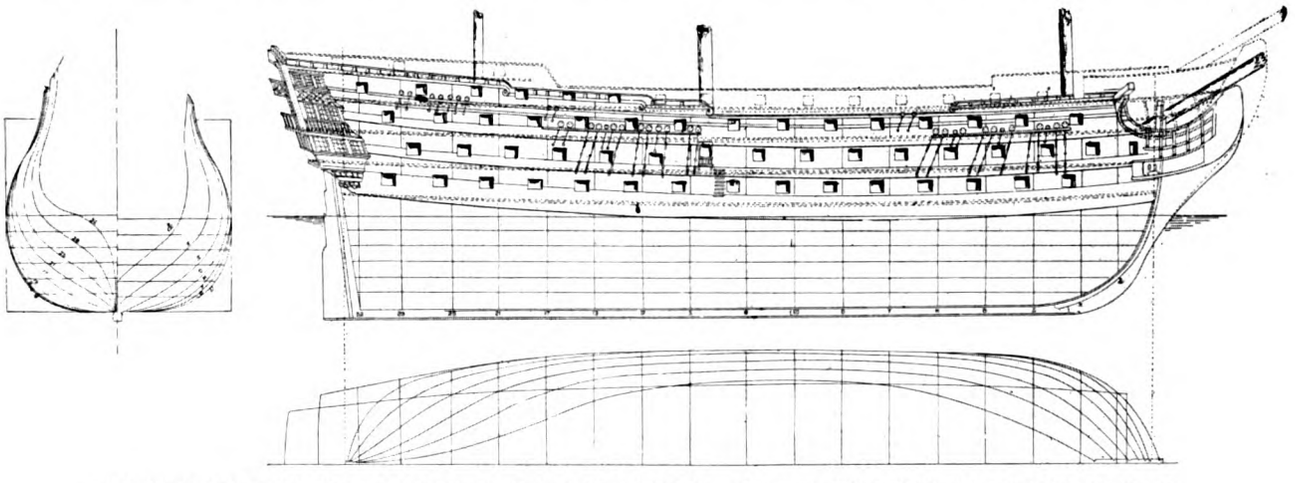
BY G. PINHORNE, M. I. N. A.

Exactly 150 years ago, in the Royal Dockyard at Chatham, was laid down the keel of the famous *Victory,* Nelson's flagship at Trafalgar. This eighteenth century relic, many times restored, but with much of the original oak timber work preserved within her, still floats near the entrance of Portsmouth harbor, where she has done duty as flagship for successive commanders-in-chief for over eighty years.

Interest in the great national hero and the old vessel, with which his name is imperishably associated, has been much stimulated in recent years by the work of the Navy League, as well as by the historical studies of Capt. (now Admiral) Mahon and other naval writers. In connection with this revival, one of the most novel and appropriate methods adopted to perpetuate the structural form, if not the name, of the vessel, was to have a steel-built ship as naval training school for poor lads, on the actual lines of the *Victory.* This idea was successfully carried out and the modern-built *Victory* took the name and place of an old wooden-built line-of-battleship *Exmouth,* which had been doing similar appropriate duties on the Thames for many years. Professor Biles, of Glasgow University, proposed the designs for the new *Exmouth,* and, at his initiative, a thorough search was made among the Admiralty archives, which resulted in the discovery of the original sheer draft of the *Victory.* This valuable but much dilapidated document has since been carefully copied, and a reproduction of it is given herewith. It was used in conjunction with the specially prepared sectional view, also shown, to illustrate a paper read by Sir Philip



PERSPECTIVE SECTIONAL DRAWING OF H. M. S. VICTORY.



OUTBOARD PROFILE, BODY AND HALF-BREADTH PLANS OF H. M. S. VICTORY. THE DOTTED LINES SHOW THE RECONSTRUCTED VICTORY.

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Watts, director of naval construction, before the Institute of Naval Architects in 1905, the Trafalgar centenary year.

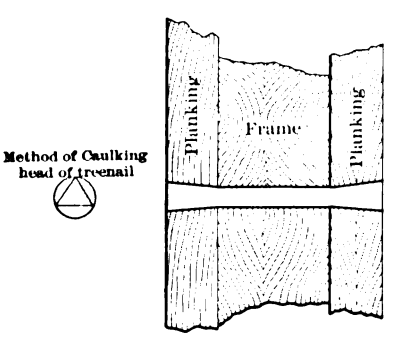
Here, then, we possess the key to an inner history of this remarkable ship, apart from, and corollary to, her oft-told achievements in 1805. To the ever-widening school of historical students and mechanics there is much of interest, something even of romance maybe, to be found in a short study of this unique product of long-past men and methods.

Upon the original sheer draft may still be traced the signature of Sir T. Slade, surveyor of the navy from 1755 to 1771, and dated "June 6, 1759." There is to be seen also a marginal note, "Named *Victory*, by order, November, 1765." This would seem to suggest that the new ship did not officially receive her name until the year of her launch. She appears to have been built to replace another *Victory*, which was lost off Alderney in 1744, with Admiral Balchen and 1,000 men.

From July, 1759, when the keel was laid, to May, 1765, when launching took place, the hull of the new ship was being slowly and laboriously pieced together on the slipway, the timbers, meanwhile, getting a certain amount of necessary seasoning. With the sectional view and supplementary detailed sketches before us, we may roughly estimate the work done and the manner of its doing.

First, the heavy pieces of the main keel, about 20 inches deep and 16 inches broad, were laid straight and true upon the blocks; they were of tough English elm, scarfed together in as long lengths as procurable. Then came the floors or lower parts of the frames, laid crosswise, and of similar sectional dimensions to the keel and tapering towards their outer ends. For the purpose of "breaking joint," these were placed with a long and a short arm, alternately on one side the keel. Upon this assemblage, and firmly secured to it by 1½-inch bolts, came the keelson, about 14 inches square, thus forming the backbone of the structure, which then gradually grew in breadth and length.

Magnificent as were the oak forests of this generation, no trees were of sufficient size to make a complete rib or frame of such a ship. Each frame was, therefore, built up of five or six separate pieces or futtocks, each futtock being of smaller section than that below it. These outreaching arms were temporarily held in place by means of horizontal rib-bands and vertical props or shores. Where their whole curvature and positions correctly corresponded with the lines of the ship's body taken from the mold-loft floor, the angle chocks were fitted at their joints and doweled together, as shown by the sketches. All the midship frames were erected

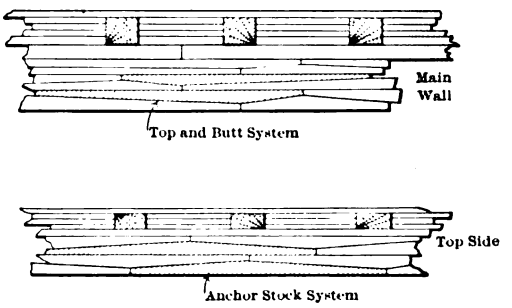


TREENAIL FASTENING.

squarely to the keel line; those at the tapering sections of the bow and stern were set obliquely or horizontally as circumstances demanded. Meanwhile, strakes of the external and internal planking were being worked upon the frames and secured by treenails "of dry, seasoned, English oak of the growth of Sussex," as the specifications set forth. We have illustrated this form of fastening, and it will be readily seen that a tightly driven treenail, well calked at each end, had considerable holding power and could not be taken out, except by boring with an auger. It was also not so liable to "work" as an iron or other metal fastening.

It will be noted that the outer planking varied in thickness. At the waterline the main wales were about 8 inches thick; these, with the thickness of frame and inner skin added, gave a protection of about 2 feet of solid oak at this vital region. The planking at the topsides was reduced to about 4.5 inches.

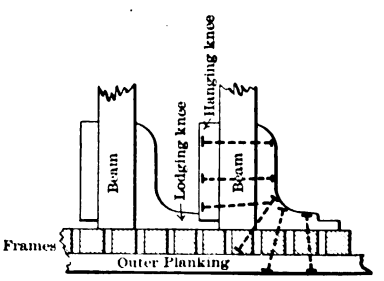
Our detailed sketches of portions of the ship's side show methods largely adopted for working the thicker strakes of



SIDE PLANKING, SHOWING METHOD OF USING TIMBER ECONOMICALLY.

plank so as to economize material. By sawing out the slabs into the "anchor stock" or the "top and butt" form the wider portions of the tree trunk could be better utilized than by cutting the planks with exactly parallel sides. Suitable timber was always difficult to obtain, and many ingenious expedients were adopted to obviate waste at the sawmills, or to use up odd pieces. The timber converter was an important appointment in the dockyard staff, and he became an expert in detecting faulty material and in adapting the natural curvature of any balk to its best service.

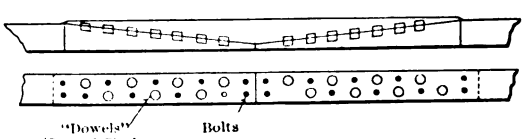
On the inside of the ship at the level of the various decks a number of extra thick planks were worked, known as clamps, and upon these rested the heavy deck beams, some 12 inches deep and 14 inches wide at the lower deck. By means of hanging knees fitted vertically underneath and by lodging



PLAN OF BEAM-END CONNECTIONS.

knees fitted horizontally at the sides, these huge timbers were efficiently connected with the sides of the vessel and offered considerable resistance to alteration of transverse form, as well as supporting the heavy tier of guns on the deck above. These beams were rarely obtainable in one piece, and the usual method of scarfing beams at this period is well shown in the sectional view.

A detailed sketch explains the system of fastening the scarfs by means of dowels and bolts. The dowel or cylindrical plug was about 3 or 4 inches long, and was commonly let in half



METHOD OF SCARFING A BEAM, SHOWING DOWEL AND BOLT FASTENING.

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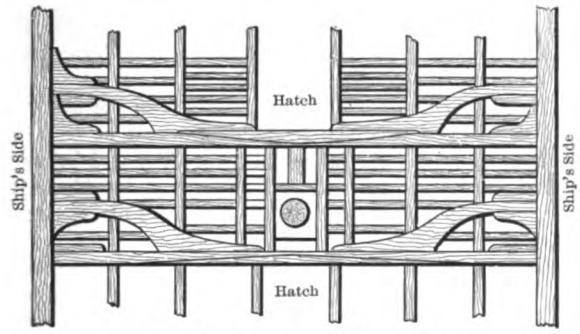
way on the faying surfaces of any jointed parts liable to work or slide under severe stresses.

If possible, a deck beam was placed under each gun position; where, however, the masts or hatchways interfered with the fitting of whole beams, a short, crooked half beam was used to take the weight of gun, as shown by the plan of the deck



DECK PLAN IN WAY OF MAIN MAST, SHOWING ORDINARY AND CROOKED BEAMS FOR SUPPORTING DECK IN WAY OF HATCHES.

framing in way of the *Victory's* mainmast. When grown timber of sufficient size could not be obtained for the beam knee pieces, a straight-grained piece or chock was used, with iron side plates to join the beam, chock and ship's side together. The spaces between the main beams were filled up by lighter intermediate framing, about 5 inches by 4½ inches. This gave a foundation to take the fastenings of the deck planks.

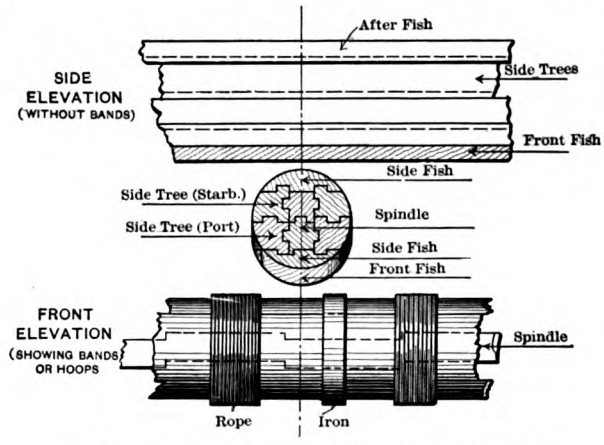
To fasten the deck, both treenails and dumps, a kind of large nail, were used; the heads of the latter were punched well below the surfaces and neatly covered by small diamond-shaped plugs, many of which may still be seen on the vessel. The decks were supported at the middle line by a series of stanchions or wood pillars, placed usually under each main beam at each deck and diminishing in diameter from the lower tier, stepped into the keelson, to the upper tier under the upper deck.

Huge pieces of grown timber of more or less angular form, arranged either horizontally or vertically, held together the sides of the vessel at the narrowed extremities and connected the stem and stern posts with the keelson. To satisfactorily connect one of these portions, known as the deadwood, through bolts some 14 feet in length were necessary. These bolts were clenched at each end and were of iron; copper bolts came into use for this purpose about 1783.

As soon as all the inner planking was in place, the heavy double riders were worked at intervals right across the hull from the height of the lower or orlop decks on each side. The head of one of these riders appears in the view of the cockpit where Nelson spent his last moments, and which was situated on the after end of the orlop deck. These stiffened the underwater body of the structure transversely, but, as the critical reader has perhaps already noted, there was little provision, beyond the inner and outer planking, to resist longitudinal bending. A tendency to hog or drop at the extremities, forming an arched or hollowed keel line, was a common fault with these vessels after several months' sea service. This was well known to the early builders, and handicapped them in any attempt to give their vessels increased dimensions. Increase of length meant assuredly increase of trouble in this direction, and perforce they added another deck to their stature to get any additional armament. The rocking stresses occasioned by carrying these heavy top weights were somewhat obviated by giving the sides of the ship considerable tumble-home, as shown by the sectional view. This allowed the upper guns to be placed nearer the center line of the ship. It was not until after Trafalgar, in 1810, that the hogging difficulty received successful treatment at the hands of Sir R. Seppings. His was simply a more scientific arrangement of materials. He omitted much of the inner bottom planking and a bridge-like combination of diagonal trusses and braces worked upon the frames throughout the greater length of the hold and treated the top sides, in way of the gun ports, in a similar manner. When one remembers that after a hard day's battle a great deal of these old ships' upper works were actually shot through or badly damaged, it is not surprising that such a structure, with her chief longitudinal ties cut away, should break and suddenly sink.

Sir R. Seppings also advocated the abolition of the bulkhead or thwartship partition at the forecastle. Being but a light wooden screen, it afforded but little protection from a raking fire, and the *Victory's* upper deck crew suffered severely on this account at Trafalgar. Instead, therefore, of ending the topsides of the vessel thus abruptly, he carried them in a natural curve to the stem piece and gave additional room with better appearance and protection. A comparison of the modern *Victory* with the original profile will make this alteration clear, as will also a reference to the special front view of the bulkhead. The doors here shown provided facilities for the men to work the head sails.

An excellent example of the piecing together of small timber, to make a thoroughly reliable combination, is afforded by the mast construction of these times. A portion of the



CONSTRUCTION OF LARGE MASTS, SECTION NEAR UPPER DECK.

mainmast, near the upper deck, of a vessel of the original *Victory* class is here shown. Its careful inspection reveals to us something of the nature of the proverbial Chinese puzzle. The *Victory's* original mainmast would have been about 200 feet in length, from waterline to truck, and about 39 inches greatest diameter. She was one of the fastest vessels of her class in the navy, with an average speed of 4 to 5 knots. The speediest frigates of the day probably reached 8 or 9 knots. At sacrifice of some sentiment we hasten to add that the masts at present fitted to the *Victory* in no way resemble those we have indicated. They are about 4 feet shorter than the originals and are made of iron. It may be explained that they really belonged to the British iron screw frigate *Shah*, which rendered herself famous by an engagement with the Peruvian monitor *Hussar*, in 1877.

At the battle of Trafalgar the armament of the *Victory* actually consisted of 104 guns, made up and distributed as follows:

Lower deck	30 long 32-pounders of 36 cwt.
Middle deck	30 24-pounders of 36 cwt.
Main deck	32 12-pounders.
Upper deck	8 short 12-pounders.
Upper deck	2 short 32-pounders.
Forecastle deck	2 short 68-pounders.

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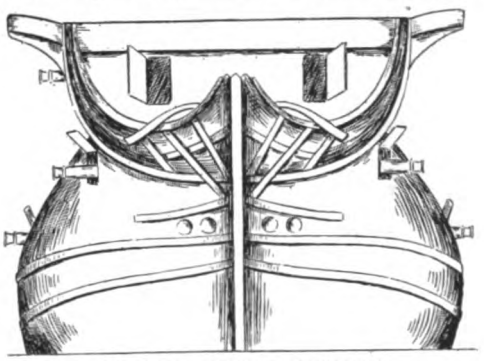
For many years it was believed that only four 24-pounders remained in the vessel of the original armament. In 1906, however, evidence was forthcoming which satisfactorily proved that there were also eight 32-pounders in the lower deck, which had equal claims to originality. These cannon were all of cast iron, and mounted on wooden carriages at 8 degrees elevation; the 24 or 32-pounders had an effective range of about 2,000 yards. In action, especially at close quarters, these guns were double or treble-shotted. Taking



SKETCH OF BOW VIEW OF VICTORY.

an average of two to three shots per discharge, the *Victory's* weight of broadside fire, in modern terms, would be about 2,500 pounds.

What little machinery was used aboard these early craft was of a simple character, and human muscle was the universal motive force.

Grouped around the mainmast on the lower deck were the pumps for clearing the leaky bilges, a water course or channel being formed on either side of the keelson throughout the ship's length. Four chain pumps and one or two suction pumps were probably the original equipment, although supplementary modern fittings may now be seen. Each chain pump, about 7 inches in diameter, had a continuous sprocket

SKETCH OF STERN VIEW OF VICTORY.

chain, carrying closely-fitting disks or cups, working in trunks or barrels that reached down into the well formed around the heel of the mainmast. They were driven by long well-manned crank handles, were fairly efficient, and rarely got out of order. The simple suction pumps were worked by long, lever handles. A lead pipe or scupper conveyed the water overboard through the ship's side.

Two sets of large wooden capstans were provided, one set placed just abaft the foremast, and the other abaft the mainmast on the lower and middle decks. These were used for working the anchors, each about 2.5 tons in weight, and for any heavy lifting or haulage operations. They were revolved by twelve long ash-wood bars, fitted into a crown of nearly 6 feet diameter, and were usually made with upper and lower drums, so that they could be manned on either or both decks if desired. Simple drop-pawls on the lower rim of the capstan prevented return or reverse motion. The hemp cables used for heavy work were 8 inches in diameter. Sir Walter Raleigh (early seventeenth century) records the introduction of the chain pump and capstan for use on shipboard, and this affords us a typical instance of the unprogressive character of naval science during the two centuries ended by Trafalgar.

The steering gear consisted of a horizontal barrel, mounted in bearings upon two stout stanchions between the upper and quarter decks, and revolved by a hand wheel at each end. Hide ropes connected the barrel with the tiller-end below the main deck, and were so arranged through pulley blocks and fairleads as to give the least possible slackness of rope at any angle of tiller.

The pulley in the form of tackle, the wedge in the form of quoins under the breech, and the hand spike or lever were the elementary mechanical appliances used for training, elevating and otherwise manipulating the guns. Loading, ramming, cleaning, etc., were simple manual exercises, as was also the transport of powder and shot. Sighting was usually a question of deciding to which part of the rigging of the opposing

SKETCH OF COCKPIT SHOWING HEAD OF HEAVY DOUBLE RIDERS.

ship the gun should be directed, so that the shots should strike her hull. Tabulated notes were kept, giving the various parts of rigging to be aimed at when at different ranges. A lighted match, applied at the breech, discharged the gun.

For the working of yards and sails several forms of tackle were used as at present; the remarkable rapidity and precision with which the most involved operations were performed depended largely upon the possession of an active and well-disciplined crew.

Before commissioning, the vessel was coated with an anti-fouling mixture made of pitch, tar and sulphur, below the waterline. Copper sheathing for this purpose was used after 1780.

The principal dimensions of the *Victory* were as follows:

	Feet.	Inches.
Length on the gun decks	186	..
Length of the keel for tonnage	151	3⅝
Beam, extreme	51	10
Beam, molded	50	6
Depth in hold	21	6
Tonnage	2,162 22/94 tons.	

Having briefly described the ship and her equipment, we may turn for a few moments to the interesting records of her career.

Her early years appear to have been exceedingly prosaic, in striking contrast to a future filled with historic and brilliant achievement. After her launch in 1765, she remained in reserve for thirteen years, doing no active service. In 1778 she was commissioned as flagship to the Hon. A. Keppel, and took part in a successful attack on a French fleet off Ushant. Under Admiral Kempenfeldt, near the same place, in 1781, she assisted in capturing fifteen merchant ships and sinking their convoy of four French frigates. She was present, under Lord Hood,

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at the capture of Toulon in 1793. At the battle of St. Vincent, in 1796, she captured the *Salvador del Mundi* of 112 guns. For about two years she was used as a hospital and prison ship for prisoners of war, and appeared likely to end her days as a hulk. However, in 1798 it was decided to modernize her, and the upper decks were entirely reconstructed. She was completed about 1803, and the dotted lines on the original sheer draft show the general effect of these alterations. On completion, Nelson chose her as his flagship, and in the same year she captured the *Ambuscade*. Two years afterward, with the same admiral, she formed part of the historical fleet of twenty-seven British ships that fought the great fight with thirty-three French and Spanish ships off Cape Trafalgar, capturing nineteen of the enemy's ships but losing their own immortal commander in the hour of his most stupendous success. The calculating student may have noted that the *Victory* was actually forty years old at this famous battle. "Too old at forty" may apply to *some* modern men and to all modern battleships, but not to the naval *material* of those days. In 1808 we find the *Victory* again a flagship in the Baltic, and then in 1812 she was commissioned for the last time. No less than six admirals applied for her as flagship in 1815, but the long war period having now ended she was not again fitted out.

In 1830 she underwent another extensive refit, and five years subsequently began her duties as flagship in Portsmouth harbor, which have continued to the present day. About twenty years ago she was thoroughly overhauled, replanked and refastened in Portsmouth yard.

In 1891 a proposal was made to take the old vessel round to the Thames and moor her off Greenwich, in connection with a great naval exhibition held at Chelsea. Although this idea was never carried out, the ordinary sightseer in London and provinces had an excellent opportunity of realizing both the internal and external appearance of the ship by means of a full-sized replica, from waterline to bulkwarks, built up in the grounds of the exhibition.

It will be recalled that just over a year ago the *Victory* had a narrow escape from destruction. Lying close to the fairway near the harbor entrance, she was accidentally rammed by the dismantled hull of the obsolete ironclad *Neptune* (1878), which was being towed away to the ship-breakers. Serious leakage was discovered, and it was officially discussed whether any repair was possible or advisable. However, largely owing to the timely intervention of His Majesty the King, the interesting old relic was saved and received a thorough repair.

Following this dramatic incident came an influential movement for the complete restoration of the *Victory* to her actual appearance at Trafalgar, or, at least, a removal of some of the most glaring anachronisms in external contour. It received sufficient consideration for rough estimates to be proposed for carrying out the work, but the matter has apparently been shelved. One step, however, has actually been taken to give some old-time verisimilitude to the present outlines. Three old-fashioned poop lanterns have been affixed to the stern, similarly arranged to those shown on our illustration of an eighteenth century ship. It is interesting to record that these lanterns, about 5 feet in height and painted yellow, were made by the naval artificer apprentices in their floating workshop at Portsmouth.

Although some differences of opinion exist as to the actual coloring of the famous vessel in 1805, it is highly probable that she was painted in Nelson's own black and white cheques, and retained the vermilion inboard works of contemporary usage. To substitute these colors for the present black and white cheques would be an inexpensive concession to archæological reformers.

The *Victory* is undoubtedly the best existing example of an eighteenth century man-of-war. A few others still remain as hulks or depot ships in and about the Royal Dockyards, or as training ships around the coasts, but their numbers dwindle each year. Some recent specimens when broken up have evidenced a remarkable state of preservation. With, therefore, a tolerant, if not altogether sympathetic, Admiralty to undertake periodical survey and repair, coupled with the jealous watchfulness of the growing body of naval students, the old vessel should be spared for many generations to come as a typical example of early marine architecture.

THE GREAT EASTERN.

During the middle half of the nineteenth century the term "engineer" reached perhaps its widest latitude; it, at least, had few of the limitations at present set by modern specialization. Any mechanical problem with iron and steam as chief factors came readily within its significance. Wherever the ancient coach builder, or shipbuilder in particular, failed to annex the new ground opened up by mechanical traction or iron construction, the vacant territory was at once occupied by the colonizing engineer.

When, therefore, in 1852, I. K. Brunel, tunnel worker, bridge builder and architect, docks superintendent and railway engineer, suggested to the Eastern Navigation Company the possibility of building a steam vessel much larger than any then existing, and, by virtue of her increased dimensions, making much more lengthy voyages at higher speeds, no one was greatly surprised. Nor when the design and construction of such a ship were entrusted to John Scott Russell, formerly college professor and civil engineer, and finally head of a shipbuilding establishment at Millwall, on the Thames, was there any professional comment. The surprise came when the actual dimensions of the proposed vessel became known; then all the world, including the professions, marveled.

This "Leviathan," afterwards rechristened *Great Eastern*, was to have an over-all length of nearly 700 feet, or more than twice the length of the previous monster ship the *Great Britain*, which in turn was already 100 feet longer than any existing line-of-battle ship!

True it was that the daring projectors of this colossal floating structure had had some special experience calculated to fit them somewhat for a task of such magnitude. Brunel had assisted at the building of the *Great Western* of 1838, the largest and fastest wooden vessel of her time. Convinced of the economical value of big ships, but also of the impracticability of constructing them in wood, he had himself subsequently undertaken the task of building the aforesaid *Great Britain* (1839-1843), of unprecedented dimensions, in iron. His co-worker, Scott Russel, had been associated with a shipbuilding firm for some years, but his peculiar fitness for the entirely new problem now submitted to him was his intimate first-hand knowledge of ship forms and resistance. A life-long experimenter with small-scale models, he undoubtedly helped largely to foster a line of research which has resulted, in our own time, in the establishment of experimental tanks for similar purposes at all important naval centers. What Scott Russel did not know concerning the relation of under-water form to speed and other kindred basis theories in ship design few, in his day, were able to inform him. Still, even with such men as these behind it, the project was a stupendous one.

Encouraged by the success in small vessels of his famous "wave-theory" of ships' lines, Scott Russell at once embodied the principle in his design for the *Great Eastern*. The waterline length of 680 feet was divided into a parallel middle body of 120 feet, with an entrance of 330 feet and a run of 230 feet, formed on the new theory. This innovation in design was

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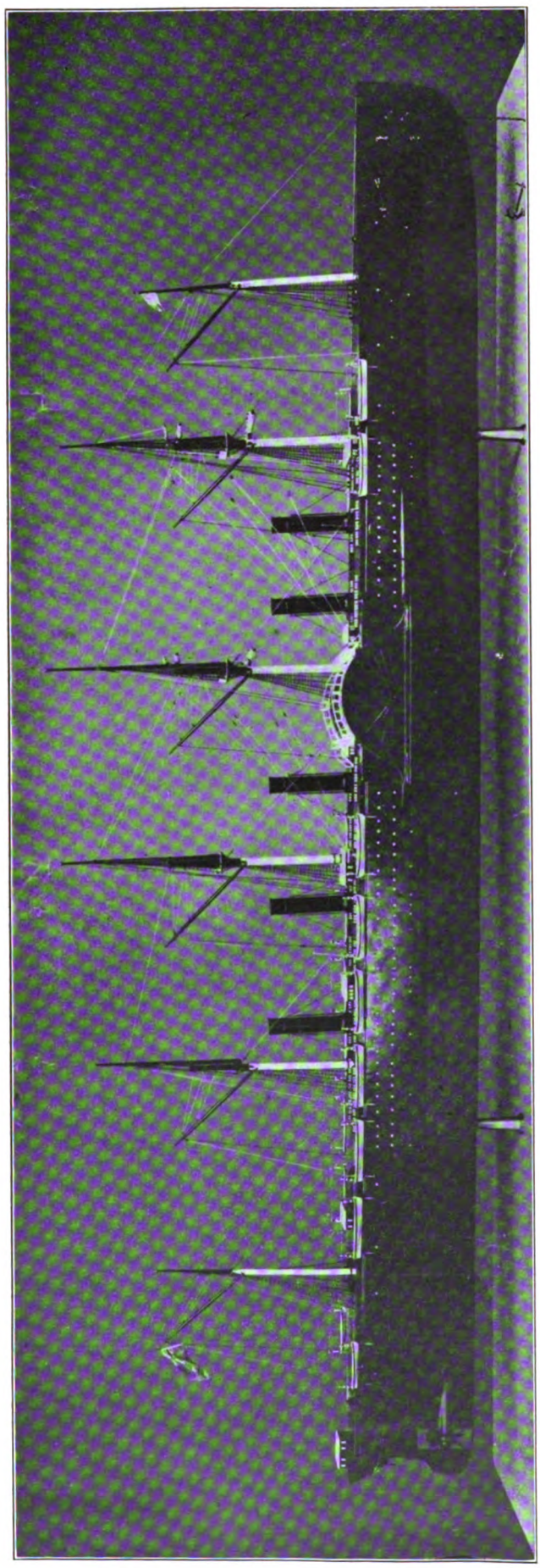
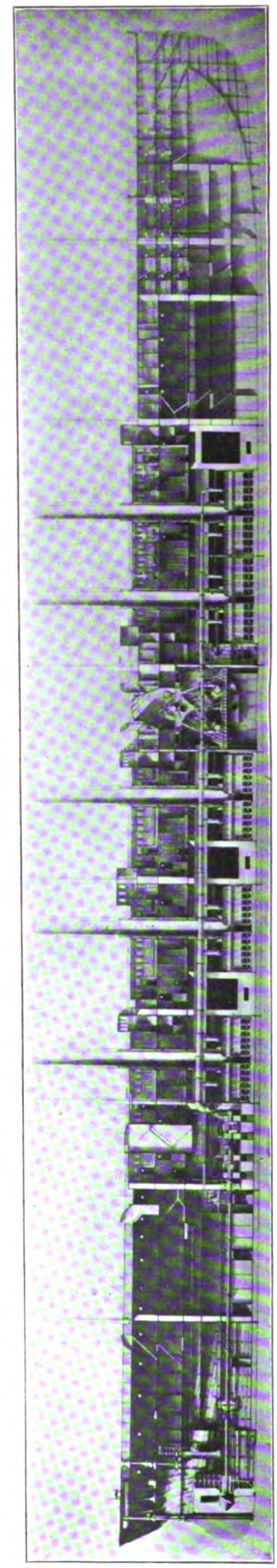


MODEL OF THE GREAT EASTERN.



INBOARD PROFILE OF THE GREAT EASTERN.

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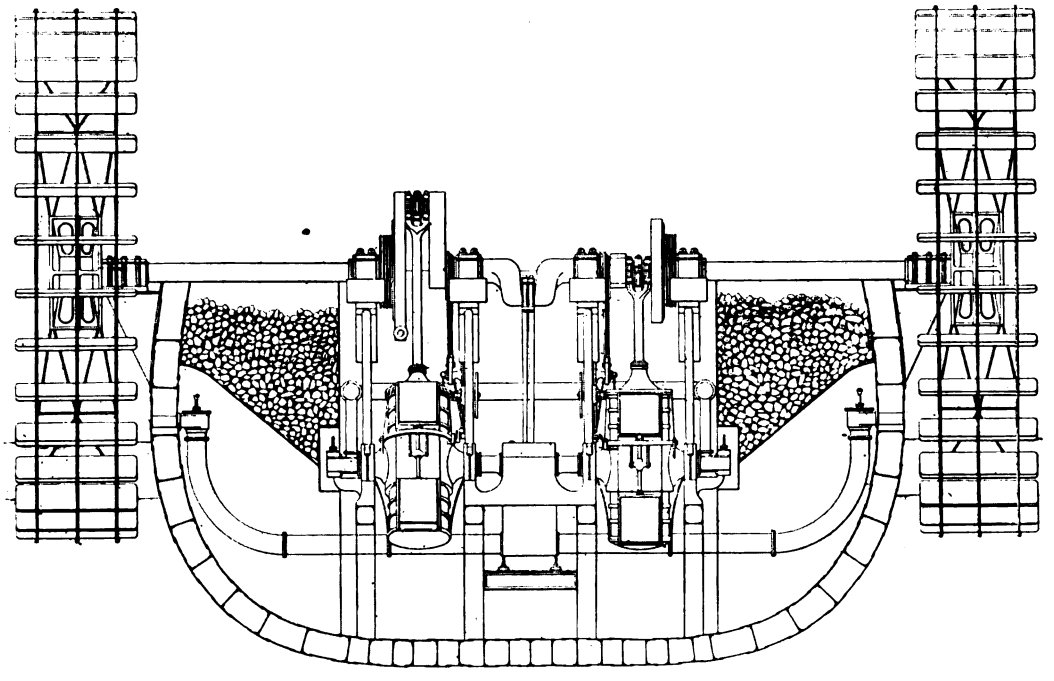
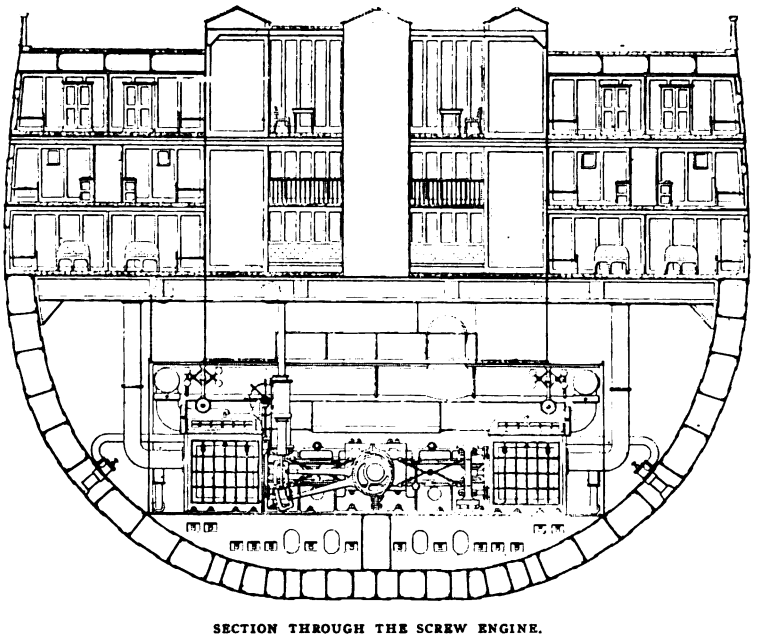


SECTION THROUGH PADDLE ENGINE ROOM OF THE GREAT EASTERN.

coupled with some still greater novelties in general construction.

First, the hull would be practically a floating bridge structure. Brunel's experience in connection with the building of the Britannia tubular bridge across the Menai Straits, and Scott Russell's actual experiments in the building of small ships, had taught both responsible architects the immense value of the longitudinally arranged girder in any structure, floating or otherwise supported, having great proportional length to breadth. Therefore, the closely-spaced transverse ribs, largely a tradition of the wood shipbuilders, were entirely abolished in the new ship, and the whole under-water portion of the hull formed of a number of continuous fore-and-aft girders or frames. When connected with an inner and outer skin of stout plating, and sub-divided by a number of widely-spaced 'thwartship plate frames, this made in itself an immense cellular girder of great strength and safety. The upper deck, or the top flange of this girder hull, was likewise of double or cellular formation. Further longitudinal assets of considerable value were two main bulkheads extending parallel, 36 feet apart, over the whole 'midship length of the vessel. The necessary transverse stiffness and internal sub-division were obtained by a number of cross bulkheads, intact below the second deck. These were so arranged as to provide five separate boiler rooms and two separate engine rooms, each 40 feet in length, as well as a number of cargo holds beyond the machinery space, each 40 to 60 feet in length. Partial bulkheads or frames gave supplementary strength and subdivision in way of coal bunkers, etc., and at the extreme ends of the ship an elaborate system of watertight compartments was followed out.

It is an interesting commentary on the so-called "longitudinal system," as here adopted in its entirety, that, though most modern ship constructors have largely adopted a compromise system, partly longitudinal and partly transverse, yet there has always been a distinct tendency towards fewer trans-



SECTION THROUGH THE SCREW ENGINE.

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verse and more longitudinal frames in many vessels. The Isherwood system, now on trial, and claiming to give a minimum of weight of material with a maximum of structural strength and internal space, is practically a return to the longitudinal system of the *Great Eastern.*

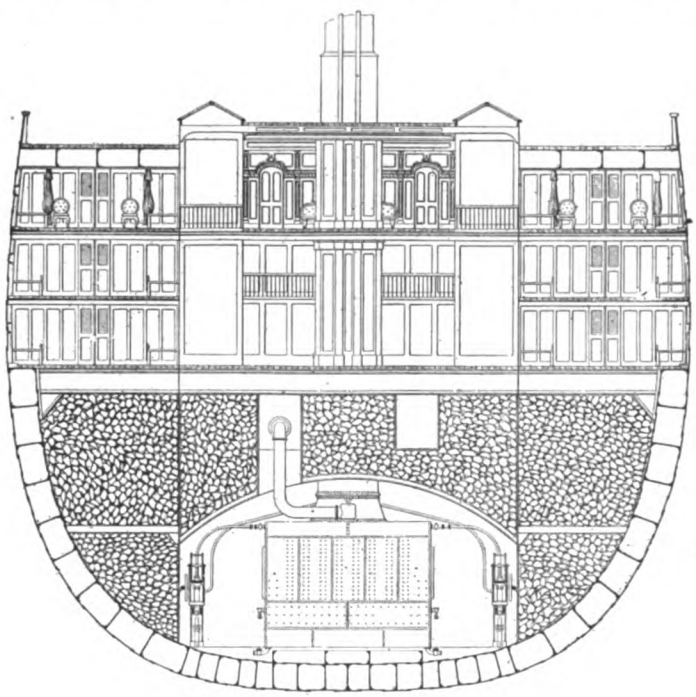
As regards the details of construction of this remarkable vessel, a marked simplicity and uniformity were observed. With the exception of some necessarily heavier scantlings at bow, stern and keel plates, all of the plates used were of equal size, 10 feet by 2.75 feet, and of two thicknesses only, .75 inch and .5 inch, while nearly all the angle-bars used were 4 inches by 4 inches by .625 inch. Further, the laps or seams of plating were single riveted throughout, the butts only being double riveted. All rivets were .875 inch diameter and spaced 3 inches apart.

As is well known, the *Great Eastern* had three distinct means of propulsion—viz.: sails, paddle and screw. That the former were not considered of subsidiary importance in a vessel designed for round-the-world voyages, may be judged by the fact that the six masts, five of which were of iron, carried about 6,500 square yards of canvas. The main yards were 124 feet long, 33 inches in diameter, and weighed about 16 tons each, the largest ever constructed.

As indicated in the longitudinal section, the paddle engines were placed about 'midships. They were designed and built by Scott Russel, who always professed a marked preference for the oscillating-cylinder type for this purpose. Their general character may be gathered from the cross section. There were four cylinders, working in pairs upon two cranks set at right angles. Each pair was inclined at a mean angle of 22.5 degrees from the vertical, and formed a complete engine in itself, with independent condensers, gearing, etc., friction clutches being provided for hand use when necessary to disconnect. Each cylinder had a diameter of 74 inches and a 14-foot stroke, and their immense size may, perhaps, be better realized by explaining that with rod and piston each weighed 38 tons. Gridiron slide valves with relief frames were used, one at each end of the cylinder, to reduce the length of steam passage. Cylinders and valve casings were jacketed with steam supplied at 60 pounds pressure from auxiliary boilers.

Steam to the engines was supplied at 24 pounds pressure from four double-ended tubular boilers, containing a total of forty furnaces. The original paddle-wheels were the largest ever made, each being 54 feet diameter, and weighing, with floats, over 90 tons. With about 10.75 revolutions per minute and 3,400 indicated horsepower, a speed of 7.25 knots was realized under paddles alone, the coal consumption being 6 tons per hour.

The screw engines were located near the after-end of the ship, and were of the direct-acting type, made by Messrs. Jones, Watt & Company, Birmingham. They consisted of four cylinders, placed horizontally, two on each side of the shafting. Each had a diameter of 84 inches and a stroke of 48 inches. The arrangement of connecting rods was peculiar. Double piston rods were fitted to each cylinder, carried by a common cross-head running in guides. To the cross-heads on the left-hand set of cylinders were double-connecting rods, while to the right-hand set were single ones only. As there were but two cranks, each pin, therefore, carried three connecting rods. Condensers of the jet type were adopted, one to each cylinder, and were cleared by horizontal air pumps. The slide valves were gridiron pattern, and were carried, owing to their great weight, on rollers. The valves of opposite cylinders were joined by a frame controlled by link-motion reversing gear; this was worked either by steam or powerful hand screws. Six double-end tubular boilers of the box type supplied steam at 25 pounds pressure from a total of 72 furnaces. The single, four-bladed propeller of 24 feet diameter weighed 36 tons. With about thirty-eight revolutions per minute and 4,800 indicated horsepower a speed of 9 knots was attained by screw alone. When proceeding under paddles or sails alone, the screw-shaft was disconnected, and two 20-horsepower auxiliary engines kept the propeller in motion. With screw and paddles in use a speed of 15 knots was reached, with a coal consumption of about 12.5 tons per hour. She had a capacity for 6,000 tons of cargo and 10,000 tons of coal.



SECTION THROUGH THE BOILER ROOM.

The arrangement of coal bunkers is well shown in the cross sections of the vessel, which are reproduced from Scott Russel's monumental treatise on shipbuilding (1864).

Some important events in the career of this famous ship may be briefly chronicled. The first keel plates were laid in May,

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1854, and the vessel was ready for launching in October, 1857. Owing largely to the experiment of using iron launching ways, in place of wood, there was considerable difficulty in getting the great broadside hull, weighing 12,000 tons, into the water. This operation lasted three months, and caused financial difficulties, which in turn hindered rapid progress of work upon the ship. She made her first trial trip in September, 1859, and her first trans-Atlantic voyage in 1861. An accident at about this period tested the efficiency of her double skin. Striking some submerged rocks she ripped an opening some 85 feet long and 4 feet wide in her bottom plating, but proceeded safely to her destination. After several unremunerative trips to New York she was utilized by the British Government for the conveyance of troops. Her accommodations provided for 800 first class passengers, 2,000 second class and 1,200 third class, or a total of 10,000 troops could be carried.

From 1865 to 1873 she did some useful work in laying submarine cables in various parts of the world, after which she lingered as a show shop around the coasts until 1888, when she was sold to the ship breakers at the price of old iron.

The commercial failure of this great vessel was undoubtedly partly due to the fact, as asserted by Scott Russel, that "she was the victim of experiments which had nothing to do with her original design." It must not be overlooked, however, that she never realized her estimated speed by several knots. Her machinery was not powerful enough to drive either set of propellers at efficient speed, and her coal consumption, per nautical mile traveled, was excessive. Overhauled and fitted with twin-screw machinery of modern make she probably could have been usefully employed down to the present day.

Until the commencement of the present century the *Great Eastern's* huge dimensions were unrivaled in the shipping world. When the White Star Liner *Oceanic* broke this half century's record her achievement was associated with commercial success. G. P.

The Introduction of the Screw Propeller Commercially.

The screw propeller was introduced simultaneously by Smith in England and by Ericsson in the United States. Each considered himself the inventor of the screw propeller, and each took out patents in England in 1836 and in the United States two or three years afterwards. Each built small screw vessels in England that were successfully tried in 1837, Smith's being of 6 tons burden, with a wooden screw driven by a 6-horsepower engine, and Ericsson's, named the *Francis B. Ogden,* having about double the tonnage and power. Each built larger screw vessels that were successfully tried in England in 1839. Smith's vessel, the *Archimedes,* which was upward of 200 tons burden and driven by 90-horsepower engines designed by Rennie, circumnavigated the Island of Great Britain in May, 1840. Ericsson's vessel, the *Robert F. Stockton,* smaller, and with less power, was tried in England under steam, and then in April, 1839, crossed the Atlantic under sail. Each introduced the screw propeller on merchant vessels in 1840, and each introduced the screw propeller on war vessels in 1843—Ericsson on the *Princeton* and Smith on the *Rattler.*

Ericsson's propeller, as applied to the *Robert F. Stockton,* consisted of two screws, one right and the other left-handed, placed one behind the other, the aftermost one being operated by a shaft passing through the shaft of the forward one. The rudder was placed forward of the propellers. This arrangement was not successful until one of the screws had been dispensed with and the rudder placed aft of the propeller. The form of the propeller itself, though fairly effective, was inferior to the ordinary screw now in use. It consisted of a cylinder, to the outside of which the blades were attached.

Prior to 1836, when patents for the screw propeller were taken out by Smith and Ericsson, the subject of crossing the Atlantic Ocean by steam had been widely discussed on both sides of the ocean, and steps had been taken for regular communication across the ocean by means of paddle steamers. This was effected in 1838 by the *Great Western,* but the difficulties of the paddle-wheel for ocean navigation were then, as now, generally admitted, so that from this time on a decided impetus was given to the development of the screw propeller for ocean navigation.

THE ADVANCE OF MARINE ENGINEERING IN THE EARLY TWENTIETH CENTURY.*

BY ARTHUR J. MAGINNIS.

It is not out of place to note this review as being that of a new century, owing to the coincidence that it practically relates the advance of entirely new departures from the well-known forms of reciprocating and piston engines which hitherto were embraced under the simple name "mechanical engineering." This will be clearly demonstrated by the fact that, after consideration, it is found to be unnecessary in any way to touch upon the numerous intricacies and doings of reciprocating machinery, but at once to proceed to the consideration of the new form of marine engineering, which, so far as the merchant service is concerned, commenced with the twentieth century.

The first turbine-driven craft appeared in 1894, and, after various developments, it in 1896, under the name of *Turbinia,* attracted marked attention.

Notwithstanding the excellent performances of the *Turbinia* in 1896, it was not until 1900 that the first order for a real test of this form of propulsion for a commercial venture was placed. This was given by a syndicate headed by Captain Williamson, owner of one of the Clyde River services, and in June, 1901, the *King Edward* commenced plying; it was so successful that it was followed soon afterwards by the *Queen Alexandra* in 1902. Since then a rapid adoption of the system has taken place, turbine steamers having practically superseded all others for rapid Channel services, and also for ocean-going passenger vessels of considerable speed, the first Atlantic liner fitted being the Allan liner *Victorian* in 1904, followed in 1905 by the Cunard liner *Carmania,* and the same company's *Lusitania* and *Mauretania* in 1907.

From Table I. it will be seen that practically no advance or improvement has been made in consumption of fuel since 1901, but the adoption of turbine machinery, although not actually improving upon the consumption per indicated horsepower, has brought about an advance, by the fact that it has enabled greater speed to be obtained.

TABLE I.

AVERAGE RESULTS OF MARINE ENGINES.

BOILERS, ENGINES, AND COAL.	Average Results: Turbines.				
Year	1872	1881	1891	1901	1909
Boiler pressure, pounds per square inch	52.4	77.4	158.5	197.	195
Heating surface per square foot of grate, square feet	.....	30.4	31.	38 and 43*	as 1901
Heating surface per I. H. P., square feet	4.41	3.917	3.275	3.0	as 1901
Coal per square foot of grate, pounds	.....	13.8	15.	18 and 28*	as 1901
Revolutions per minute, revolutions	55.67	59.76	63.75	87.	.....
Piston speed, feet per minute	376.	467.	529.	654.	None
Coal per I. H. P. per hour, pounds	2.11	1.83	1.52	1.48	as 1901
Average consumption on prolonged sea voyage, pounds	.....	2.	1.75	1.55	.....

*Natural and forced draft respectively.

* From a paper read before the Institution of Mechanical Engineers, July, 1909.

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Up to the present time but little progress has been made in the adoption of turbines for slow-going merchant or other vessels, owing no doubt to the difficulty of applying the turbine to the single propeller, but in no other field of operation is there such an opening for a simple form of rotary machinery. When, however, it is borne in mind that it has taken over seventy years to render all parts of the reciprocating marine machinery fit for the work, it cannot be gainsaid but that in a few years the difficulties yet to be experienced will be surmounted by the adoption of the turbine in the cargo steamer.

TURBINE MACHINERY FOR CARGO VESSELS.

In full-lined vessels of the single-screw "tramp" type, the speed of revolutions of the propeller is not so great as to allow of the propeller shaft being driven direct from the turbine rotor, so that it seems as if even for this class of

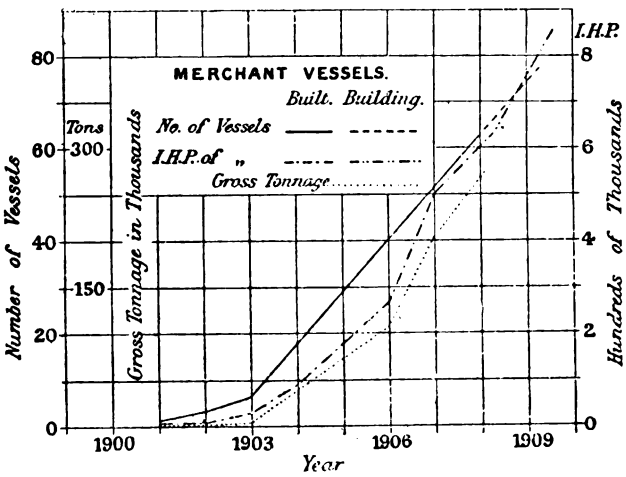

FIG. 1.—CURVES SHOWING NUMBER AND HORSEPOWER OF TURBINE-DRIVEN MERCHANT SHIPS BUILT AND BUILDING.

vessels it would be necessary (notwithstanding the increased first cost) to adopt twin or even triple screws.

It may be remembered that when multiple cranks were first adopted, it was generally remarked by those who knew that multiple cranks were all very well for high-speed mail boats, that three-crank engines would not suit the cargo tramp; whereas to-day they are fitted in all sorts, from trawlers, drifters, etc., and even five-crank engines are now found on cargo boats and six cranks on express liners. Bearing this in mind, there does not seem to be an insuperable objection to apply the turbine to slow-speed vessels by the adoption of multiple propellers, say three, as on moderate-speed liners. These propellers, smaller in diameter than the present single or twin screws, running at such speed of revolution as would allow of direct connection to turbines, could, in the author's opinion, be applied, and at but little, if any, more first cost than in existing practice; for although the cost of three lines of shafting is to be met, they would be much smaller and lighter, and the advantage of the boiler pressure being much lower would enable considerable saving of cost and weight to be gained.

ADVANTAGES OF TURBINE MACHINERY.

The marked advantages of turbine machinery in all the numerous vessels fitted up to date is so evident that it will be worth while enumerating them here, in order to point out the desirability of an early effort being made to apply them to the class of vessel now under consideration:

(*a*) The rapid changes of motion (twice per revolution) being done away with, the risk and liability due to fractures or flaws caused by concussions and shocks is altogether eliminated.

(*b*) The absence of piston rods, glands, slide valves, guides, cross heads, connecting rods, link motion and crank shafts removes all risk of undue heating and distortion of parts.

(*c*) The steady revolving motion on the shafting reduces the risk of breakage of shafts and propeller blades to a minimum, and also allows of less supervision, so that the men in charge can devote more time to the firing and working of boilers, etc.

(*d*) The avoidance of risk of serious breakdowns caused by racing in heavy seas.

(*e*) The marked economy brought about by the very great reduction in the use of consumable and other stores, such as oil, packing, etc.

(*f*) The saving in men's time in opening and adjusting and general overhauling.

(*g*) The avoidance of an extensive outfit of tools and gear necessary to effect the work.

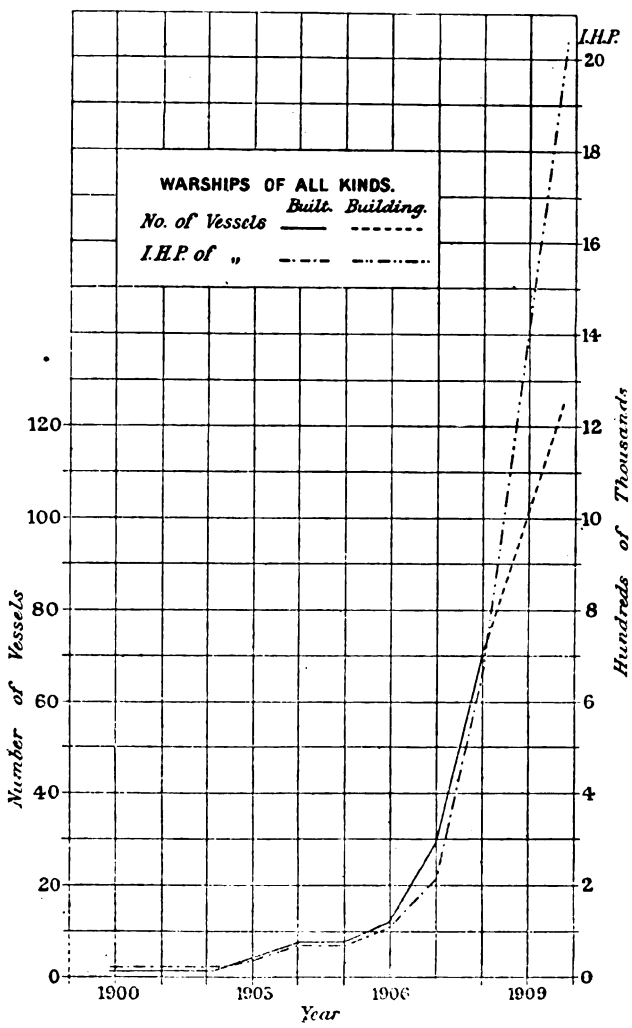

FIG. 2.—CURVES SHOWING NUMBER AND HORSEPOWER OF TURBINE-DRIVEN WARSHIPS BUILT AND BUILDING.

(*h*) The reduction in first cost of many spare parts which must be carried for piston machinery in case of a break-down.

(*i*) The lowering of boiler pressure, which has allowed of an extensive reduction in weight and first cost.

(*j*) Another advantage is that the past eight years have shown that the Parsons turbine machinery will not break down or stop. From extensive enquiries which the author has made, notwithstanding that there are now over seventy steamers continuously plying to and fro, no sailing schedules have been upset by a failure of machinery up to the present, nor has a turbine steamer ever had to be towed into port.

On the other hand, beyond the difficulty of keeping down the

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speed of propeller revolutions to suit the turbine, the objections against its adoption are not very serious; apparently some cargo space will be absorbed by having two or three tunnels aft, but this can be partly compensated for by a considerable reduction of engine-room opening through the decks upward. The risk of breakage of propeller blades will no doubt be put forward; but this all recent experience has shown in reality is no greater than with the single propeller.

By consideration of the foregoing facts, it will be seen that the only (but naturally the most important) feature which has so far been against the use of turbines for cargo boats, is the mechanical one of relative speed of turbine rotor and propeller, and this problem will undoubtedly gain much attention in the near future.

In order to show how rapidly turbine machinery has come to the front, Figs. 1 and 2 have been compiled, and from these it can be seen that the adoption of turbine machinery for main propulsion has been extremely rapid, rising in the merchant service from one steamer and 3,500 horsepower in 1901 to sixty-four steamers and 603,200 horsepower in December 1908. There is no doubt that the adoption will become increasingly rapid in the future as the system spreads among all classes of steamers.

COMBINED PISTON AND TURBINE MACHINERY.

An instance of the striving after improvements on the machinery of steam vessels is illustrated by Fig. 3, which is an outline arrangement of the combined system of piston and turbine engines recently built by Messrs. Denny, of Dumbarton, for the direct New Zealand service. This was fitted on the steamship *Otaki* of the New Zealand Shipping Company, London. The adoption of this combination has been brought about by the efficiency of the turbine system when working on the vacuum, as the terminal pressure in the low-pressure cylinder of either triple or quadruple machinery is, as a rule, so high that it has been found there is power enough remaining to drive another or third propeller before allowing the exhaust steam to reach the condenser.

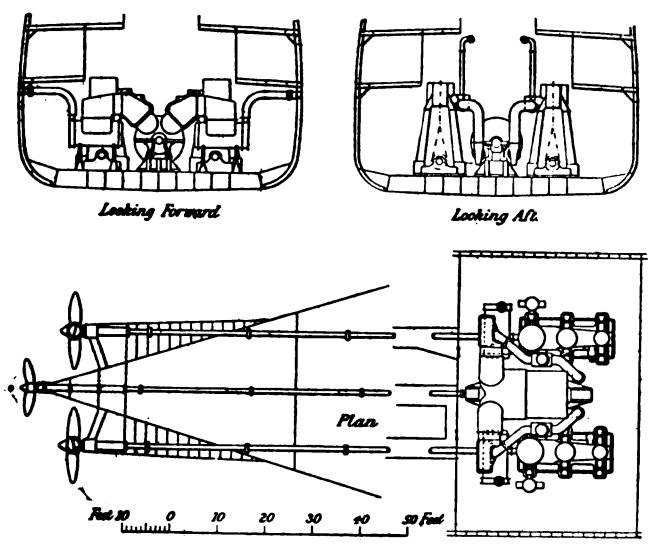

FIG. 3.—ARRANGEMENT OF COMBINED RECIPROCATING AND TURBINE ENGINES ON T. S. S. OTAKI.

The opportunity of being able to ascertain what superiority may be in this arrangement over that of ordinary piston engines was taken advantage of by Messrs. Denny, who built one steamer named the *Orari* for the New Zealand Shipping Company, and on a second one being required they induced the owners to adopt the turbine-combined system in the second boat, both vessels having the same boiler power and being built off the same lines. The result of the trial trip, which took place in October, 1908, showed a slight increase in speed of about half a knot over that of the *Orari*, and so far as can be ascertained this advantage has been maintained in the regular trade. As these twin vessels are like the *Caronia* and *Carmania*, and also the *Laurentic* and *Megantic*, of special interest for comparative purposes, it may be of some service to note their particulars:

So far as these combined piston and turbined-engined vessels have been at work, satisfactory results have been obtained; but it is evident that an extensive adoption of this system will not be made, the days of the steam piston engine for marine propulsion being numbered.

Coming now to the mechanical details of turbine propulsion, it must be noted how few there are to discuss compared with the very numerous details of piston engines. The only detail in the Parsons turbine machine since the shape and formation of the blades in both the stator and rotor have been fixed by its inventor, is the fastening of the blades or vanes, and this is of such a simple nature that all difficulties have been surmounted, and so far as the turbine proper is concerned the wear and tear are trifling. No doubt in some cases trouble has been experienced in straining in the rotors, due to centrifugal action, and it has been found that rapid corrosion in certain parts has taken place, but a few years' further experience will probably solve and effectually remedy these and some other minor defects which have occurred.

CONDENSERS.

The obtaining of as perfect a vacuum as possible being a special factor in steam rotary engines, the question of an efficient condenser becomes all important, and it is remarkable that almost simultaneously with the coming forth of the turbine the first real efforts were made to improve upon the ordinary surface condenser existing since the days of Hall, who introduced it in 1831, and actually had it fitted on the paddle-steamer *Sirius* in 1837, and on the early Atlantic liner *British Queen* in 1839. After considerable study and experimenting of the condenser problem, it is a matter of common knowledge that it is only a few years ago that this question was given the great consideration which so important a matter deserved. After considerable study and trials, most inter-

TABLE II.

Year.	Steamer.	Length.	Breadth.	Depth.	Diameter of Cylinders.				Stroke.	Diam. of Turbine.	Boiler Pressure.	No. of Propellers.
					H. P.	I. P.	M. P.	L. P.				
		Feet.	Feet.	Feet.					Inches.	Inches.	Lbs.	
1908	Otaki	465.4	60.3	31.3	24½	...	39	48	...	39	200	3
1906	Orari	460.7	60.2	31.3	2 of 24½	...	2 of 41½	2 of 69	48	None	200	2
1905	Carmania	650.4	72.2	40.0			Turbine				195	3
1905	Caronia	650.	72.2	40.2	39	54½	77	110	66	None	210	2
1909	Laurentic	550.	67.3	32.9	2 of 30	2 of 46	...	4 of 53	54		...	3
1909	Megantic	550.	67.3	32.9	2 of 29	2 of 42	2 of 61	2 of 87	60	None	...	2

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esting results were obtained by Mr. D. B. Morison, who, acting in conjunction with Professor Weighton, succeeded in discovering hidden defects and placing the designs of condensers, Contraflo and others, on a satisfactory footing, and fully explained them in various papers read before kindred institutions. These improved condensers, with the addition of the modern improved air pumps and the vacuum augmentor of Mr. Parsons, have ensured satisfactory working and have helped to hasten the adoption of the turbine.

SHAFTING.

Owing to the adoption of balanced-piston engines and the turbine principle, the shafting of modern vessels has now almost ceased to be the source of anxiety and trouble known in the past, the shocks and uneven straining being almost altogether eliminated, so that it is unnecessary to comment upon this section of marine machinery.

PROPELLERS.

With regard to the propeller itself little can be said, as the design and style of construction have now settled down to recognized types for the various classes of vessels. It is yet largely only by trial and result that the best propeller can be found for each vessel.

BOILERS.

Coming now to the steam generator, and looking back since the last time marine engineering was brought before the Institution in 1901 by Mr. McKechnie, it is not possible to note any advance or change in the design, as no marked alteration has taken place; but the improvements in the manufacture and working of larger boiler plates have resulted in the still further reduction of riveted parts The introduction of automatic circulators, fitted inside the boilers without any working parts whatever, has materially reduced the repairs rendered necessary by the abnormal strains set up by the varying temperatures prevailing in different parts of the boiler.

In considering this question of boilers, one must not omit to call attention to the still further advantage to be gained by the adoption of turbine machinery, owing to the fact that lower steam pressure is required. What this means in saving of weight over the scantlings necessary for the boilers of quadruple and the later triple-expansion piston machinery can be fully realized when it is considered that in the case of the *Lusitania* and *Mauretania* the saving in weight on the boilers alone is about 120 tons over and above that which would have been required if triple or quadruple-piston engines had been used. This also applies in the case of the cross-channel vessels, such as the Isle of Man steamer *Ben-my-Chree,* to be seen at the Liverpool Landing Stage, the scantlings in this vessel being something like 75 tons less weight than would be required for piston machinery of equal power.

MECHANICAL STOKING.

A detail of considerable importance to the boiler room is that of the adoption of mechanical stoking of some description. This, like other subjects, has been the cause of numerous experiments and patents, but so far it cannot be said to be so satisfactorily solved as to ensure universal adoption. The fairly wide adoption of forced draft has, however, increased the difficulty, and this is much to be regretted, for there is no doubt that the want of some system is badly felt which could modify or completely do away with the arduous requirements of the stokehole of all steamers.

WATERTUBE BOILERS.

Watertube boilers have been put to work on warships, torpedo craft, and in some cases merchant vessels, but, for the most part, for the various craft associated with royal navies outside the fighting line, the Scotch or tank form of boiler is generally adopted, as also in all royal yachts and other pleasure craft. So far as the mercantile marine of the world is concerned, there are no more than 250 vessels of all classes of 300 tons and upwards fitted with watertube boilers, and of these about fifty are passenger and the remainder of the ordinary cargo type.

FUEL.

Coming now to the important question of the nature of the fuel used, even here it is to be regretted that no great advance has been made; true it is that in certain trades and on steamers favorably situated to obtain oil fuel progress has been made, but up to the present there is no pronounced sign that liquid fuel will generally supersede coal. This is much to be regretted, as there is no question but that liquid fuel presents many features to recommend its adoption for marine purposes.

Considering the advantages of oil fuel, as demonstrated from practical experience in naval and other ships, it must be admitted that if steam is to continue as the great motive power for marine propulsion, liquid fuel will sooner or later become more general, especially if the price of the material can be kept down in proportion to the large increase in consumption which must of necessity follow if it be adopted.

INTERNAL-COMBUSTION ENGINES.

Following upon the subject of liquid fuel, there naturally comes the question of internal-combustion engines, which are now being widely adopted for smaller craft and also for barges. Numerous designs for different kinds of fuel are now being put to work, and are gradually being made use of in all parts of the globe, but up to the present no ordinary cargo vessel of 1,000 tons or upwards has been so fitted, but, like other branches of marine engineering, the striving after greater economy will no doubt bring further developments.

Following upon the liquid-fuel internal-combustion engine comes the very important one of using gas generated on board the vessel. Of this it is difficult yet to express a decided opinion, as, with the exception of the now well-known suction-gas vessel *Rattler,* but little experience has been gained, and that only on smaller craft; at the same time consideration of the subject tends to raise hopes that a gradual introduction of the system may soon come about.

That a considerable number of wants for this class of machinery have yet to be surmounted cannot be denied: The want of simple and reliable reversing of propeller, ready provision for working all the numerous auxiliaries, providing heating apparatus and simple working appliances for cargo and such like, present great but not insuperable difficulties.

DIRECT ELECTRIC DRIVE FOR PROPELLERS.

The fact that the coming power for marine propulsion must be directly rotary, coupled with the success of the steam turbine, has brought forward another system, which, in the author's opinion, will soon be widely adopted, namely, the application of electric power direct to the propeller shafts. In view of the fact that up-to-date steam still remains the most simple and most useful source of power available on board ship, and can, thanks to turbine machinery, be readily and economically put to generate electricity up to great power, it will not be out of place to note the advantages likely to accrue from the adoption of direct electrical shaft drive.

In the first instance, reversal of the propeller with full, effective power is attained and readily effected. Secondly, the design of both the steam and electric plant can be so modified as to enable the naval architect to make better and more profitable arrangements for both passenger and cargo space.

The application of the electric drive and form of motor have now been so improved as to reduce wear and tear to a minimum, and has also increased the efficiency, so that prompt and reliable starting, reversing and stopping are ensured.

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Owing to the fact that the lower boiler pressure can be used by the steam turbine generator, it is anticipated that the weights of the steam and electric plants together will not exceed that of the present system of reciprocating machinery, and it is also estimated that the first cost will average about the same. Of the advantages of this system one which will commend itself to the navigating department is that the long-looked-for apparatus to control the movements of the propellers direct from the bridge may be obtained.

Another advantage is that electricity, like steam, is capable of being readily applied to all the other requirements on shipboard, such as steering, windlass and winch work, combined with the further advantages of more economical distribution and giving a simple and agreeable artificial light throughout the vessel. Its principal application would, of course, be to the slower-going cargo tramps with propeller speeds of from 70 to 120 revolutions per minute.

Should this system of main electric drive for working screw propellers direct come about, the continued decrease in the boiler pressures, as commenced with the steam-turbine machinery, will no doubt be further continued, and even lower pressures than now exist will be made use of, which will largely decrease the weight of boiler installations and so cheapen the first cost.

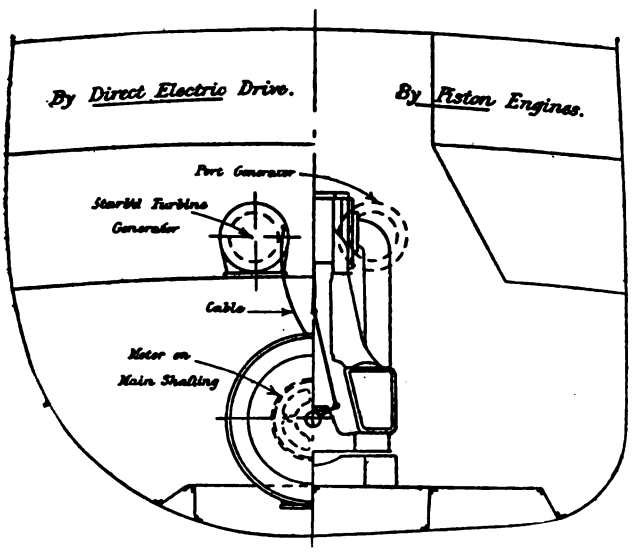

FIG. 4.—DIAGRAM SHOWING RELATIVE SPACE OCCUPIED BY TURBO-ELECTRIC AND RECIPROCATING ENGINES.

Looking back to the papers previously read on this subject, it will be seen that no such remarkable changes have taken place since the introduction of steam navigation as during the few years which have passed since the commencement of the present century. In none of the previous papers has even an allusion been made to the likely use of the internal-combustion engine or the suction gas for marine propulsion, and only in the last paper read by Mr. McKechnie in 1901 was mention made of the Parsons turbine, which is the first successful adoption of rotary instead of reciprocating or piston machinery.

Coming, finally, to the results attained by marine engineering to date they may be summarized as follows: . Vessels of close upon 800 feet in length and over 38,000 tons displacement are being propelled across the Atlantic at an average speed of 25½ knots by turbine machinery working up to about 70,000 horsepower, having a consumption of upwards of 1,000 tons per day. Similar results have been given in the turbine-propelled warship *Indomitable* of over 40,000 indicated horsepower, and maintained across the Atlantic with watertube boilers.

So far as the merchant marine is concerned, there is at present no sign that the great horsepower of the *Lusitania* and *Mauretania* will be exceeded or even equaled for some years to come, as the large vessels now under construction for the White Star Line, following the types of the vessels constructed by them during the past twenty years, are reported to have but a moderate speed of about 20 knots, so that the machinery installations will be only of very moderate dimensions and power. This latter course is also being followed by the Continental lines, all their more recent vessels not exceeding 18 knots.

RECENT WARSHIP DEVELOPMENT.

BY BENJAMIN TAYLOR.

One of the most appalling things to the economist in fiscal affairs is the rapidity with which costly warships become obsolete and have to be scrapped. Yet this apparent waste of public money is not all actual waste, and in the evolution of new types the highest technical skill in marine architecture and in engineering is evoked. In a survey of recent developments, however, it is not necessary to go back many years, since vessels which were the wonder and talk of the day, say, five years ago, are now slipping out of date. Let us, then, not go further back than 1907 and see what has been the evolution in warship production, and more especially in British shipyards.

The shipbuilding output of the British Admiralty establishments in 1907 was 37,200 tons displacement in two battleships of the *Dreadnought* class, and the contract yards (that is to say the private shipbuilding yards who build on government contracts) launched eighteen armored and unarmored vessels of 79,000 tons displacement for His Majesty's fleet. In addition, for their own ships and for the dockyard-built ships, engineer contractors constructed turbines of an aggregate indicated horsepower of 325,000, guns, gun mountings, armor and auxiliary machinery. The activity of the Admiralty dockyards is not to be measured by new work, because the establishments exist mainly for the maintenance and repair of the fleet. The details of the two ships launched by the government dockyards in 1907 are shown below:

VESSEL.	Type.	Displacement, Tons.	Built at
Bellerophon	Battleship	18,600	Portsmouth.
Temeraire	Battleship	18,600	Devonport.

The turbines for the *Bellerophon* were constructed by the Fairfield Shipbuilding & Engineering Company, Ltd., Glasgow, and the turbines for the *Temeraire* by R. & W. Hawthorn, Leslie & Company, Ltd., Newcastle-on-Tyne. The turbines for the sister ship *Superb*, built by Sir William Armstrong, Whitworth & Company, Ltd., Elswick-on-Tyne, were constructed by the Wallsend Slipway & Engineering Company, Ltd., Wallsend-on-Tyne. Each of the three installations was of 23,000 indicated horsepower.

The ocean-going destroyers *Cossack, Tartar, Mohawk, Ghurka* and *Afridi* represent certain remarkable achievements in 1907. All these vessels have excelled the designed speed of 33 knots, and have demonstrated their capability of maintaining it for over 1,500 nautical miles. They are driven by Parsons turbines, and use oil fuel exclusively. They represent ideal "scouts," as they have enormous speed, a wide radius of action, and are capable of keeping most seas with any fleet. The experimental vessel *Swift* has double the displacement of the 33-knot vessels and double their horsepower. The *Swift* was built by Cammell, Laird & Company, Ltd., Birkenhead, and the *Cossack* was a reproduction. John I. Thornycroft & Company, Ltd., London, built the *Tartar;* J. S. White &

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Company, Cowes, the *Mohawk;* R. & W. Hawthorn, Leslie & Company, Ltd., Wallsend, the *Gurkha,* and Sir W. G. Armstrong, Whitworth & Company, Ltd., Elswick, the *Afridi.* The turbines for the last-named were constructed by the Parsons Company, at Wallsend-on-Tyne. The three armored cruisers of the *Invincible* class were completed. John Brown & Company, Ltd., Clydebank, built the *Inflexible* of this class; the Fairfield Shipbuilding & Engineering Company, Ltd., built the *Indomitable,* and Sir W. G. Armstrong, Whitworth & Company, Ltd., Elswick, built the *Invincible.* The turbines for the Tyne-built ship were constructed by Humphrys, Tennant & Company, Ltd., Deptford-on-Thames, a firm which is since extinct.

It is noteworthy in shipyard development that in 1907 the four Imperial dockyards in Japan, at Yokosuka, Kure, Sasebo and Maizuru, were equipped for building warships. Sasebo and Maizuru were of more special service in reconstruction and repairs; and with this end in view these two establishments have been greatly extended. At Sasebo three new graving docks are established, having lengths of 750 feet, 600 feet and 475 feet, respectively. These two dockyards may very readily be made available for construction. The battleship *Satsuma* and the first-class cruiser *Kurama* were launched from Yokosuka; the battleship *Aki* and the first-class cruisers *Ikoma* and *Ibuki* from Kure. Kure attracted special attention owing to the very rapid construction of the first-class cruiser *Ibuki.* From the berth occupied by her the battleship *Aki* was launched only in April. The *Ibuki* was laid down in May, and launched in November, thus occupying only six months in construction on the stocks. The displacement of the *Ibuki* is 14,600 tons, against the *Dreadnought's* 18,000 tons. The time taken with the *Aki* was more prolonged, the cause being that after the ship had been commenced on the stocks a gantry was started and erected across the berth. This gantry has six traveling cranes, three spanning the half breadth and three the full breadth, each capable of lifting 15 and 5 tons, respectively, and electrically-driven in their traversing, fleeting and raising actions. The delay with the *Aki,* thus caused, was one means of the speedy construction of the *Ibuki,* the gantry proving of invaluable assistance in her case.

The next year, 1908, was remarkably interesting in naval shipbuilding, and not often has the scope of ships for warfare had such development. The British *Bellerophon* and the German *Posen,* the British *Invincible* and the German *Blucher,* provided different solutions of the same problems. The swifter vessels should hardly be called cruisers, if a cruiser is a ship detachable from a fleet without reducing its fighting strength. But their inferior protection and superior speed design them for quite other uses. They are not battleships as the *Dreadnought* is. The *Bellerophon* is the latest complete logical development of the battleship, in which the problem is not to get speed alone but to combine efficiently great destructive power at long ranges with protection against all the dangers of naval warfare and large fuel capacity and speed. The *Bellerophon* and *Temeraire* are ideal vessels of their type for the particular work British warships have to do.

BRITAIN'S BATTLE-CRUISER INDOMITABLE.

The *Invincible* and her sisters, again, are modernized ships of the cruiser type. The real cruiser, adapted to the problems of modern warfare, however, is to be found in the *Boadicea.* The *Boadicea* type was developed from the scouts of 1902-3 and 1903-4. The most serious objection to these ships was that they did not carry enough coal, and, therefore, their radius of action was poor. In the design of the *Boadicea* this deficiency was to be made good; yet insufficient coal capacity is still being urged against her. The five *Boadiceas* intended to remedy that defect are some 1,200 tons larger, and are called second-class cruisers. They are fast enough for scouting, but their armament and coal capacity are those of cruisers.

The new classification of the coastal craft as torpedo boats is due to the larger purpose which the torpedo is beginning to serve. In destroyer development it may be noted that in course of construction there are such greatly different types as the 36-knot *Swift,* the 33-knot vessels of the *Afridi, Saracen* and *Maori* type, and the 27-knot vessels of the present

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programme. The *Swift* is an experimental vessel of 1,800 tons displacement and 30,000 horsepower, with steam turbines and oil fuel. She is a destroyer with a protected cruiser's seagoing qualities. In her case everything is sacrificed for speed and endurance. She seems the ideal scout, but with wireless telegraphy and telephony perhaps the day of the scout is passing. Anyhow, the *Swift* differs strikingly from other scouts.

The 33-knot vessels under construction are essentially destroyers, although they can serve as scouts. Their specialty is ability to keep the sea in most weathers. The 27-knot vessels of this year's programme are to burn coal instead of oil; but that does not mean that the 33-knot vessels are a failure and that we are reverting to coal and less speed. These projected vessels are, except in fuel, the embodiment of the lessons learned from the earlier vessels. The destroyers of the river class were, on paper, slower than the 30-knot vessels, yet at sea they sailed round the nominally faster vessels. They were larger and they kept the sea better. One of the German destroyers, *G 137*, is credited with 33.9 knots, and the twelve *V's* under construction at Stettin are designed to do 30 knots, but the displacement of *G 137* is 572 tons, and the displacement of the Stettin boats is 670 tons, as compared with 900 tons of the British 27-knot boats, and from 950 to 1,100 tons for the 33-knot boats. The British vessels are bound to be faster in sea work. The development of the submarine is also in the direction of increased radius of action, involving greater dimensions and other qualities. The Russian submarines have Gardner engines, and the two Italian vessels run on either petrol (gasoline) or paraffin (kerosene).

The output of British dockyards in 1908 was as follows:

Vessel.	Type.	Tons.	Built at
St. Vincent	Battleship	19,250	Portsmouth.
Collingwood	Battleship	19,250	Devonport.
Boadicea	Scout	3,300	Pembroke.
C. 17	Submarine	630	Chatham.
C. 18	Submarine	630	Chatham.

The following is the Admiralty dockyard output in previous years:

Year.	Portsmouth.		Chatham.		Pembroke.		Devonport.		Sheerness.	
	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.	Ves	Tons.	Ves.	Tons.
1908	1	19,250	2	630	1	3,300	1	19,250	..	.....
1907	1	18,600	..	.....	1	14,600	1	18,600	..	.....
1906	1	17,900	1	14,600	..	.....	1	14,600	..	.....
1905	..	.....	1	16,350	1	13,550	1	16,350	..	.....
1904	2	32,700	1	10,850	1	13,550	..	.....	..	.....
1903	1	9,800	..	.....	..	.....	1	16,350	2	2,140
1902	..	.....	2	20,880	1	9,800	2	20,880	..	.....
1901	1	9,800	1	14,000	2	23,900	1	14,000	3	3,210
1900	1	2,200	..	.....	..	.....	..	.....	3	3,030
1899	1	15,000	2	17,200	1	4,700	2	30,000	..	.....
1898	1	15,000	2	27,950	1	11,000	2	15,085	2	1,020
1897	1	12,950	1	5,800	1	11,000	..	.....	1	2,130
1896	3	26,300	1	14,900	1	14,900	2	11,000	2	4,275
1895	2	29,800	2	20,500	1	12,350	3	7,700	..	.....
1894	1	5,600	1	14,900	1	1,070	3	3,219	2	1,920
1893	1	4,300	2	5,430	2	8,720	3	9,630	1	4,350
1892	2	18,300	1	10,500	1	14,150	1	4,350	4	3,240
1891	2	21,850	3	24,900	1	14,150	1	3,600	1	3,600
1890	1	2,575	1	1,340	1	2,575	3	12,500	2	1,470

All the large maritime powers in the world are either building or proposing to build capital ships of the *Dreadnought* type. Two have been built for Brazil; the *Minas Geraes* at Elswick, and the *Sao Paulo* at Barrow. Argentine has decided to order similar ships. Germany, the United States, Japan, France and Russia are either building or projecting *Dreadnoughts*, all developing the same naval idea. Some experts condemn the British *Dreadnoughts* as inferior units to the German ships of the *Nassau* class, or the Brazilian ships above mentioned. But the ships of each country are designed by experts working on knowledge that is not common to all.

The British *Dreadnoughts* are designed for the work which British battleships are built to accomplish. With them strength is concentrated in home waters in accordance with a plan that has nothing to do with naval architecture. But the British Empire is world-wide, and a slight disturbance anywhere might render necessary a new concentration of her naval force remote from home waters. Fuel capacity, therefore, is a much more important element of design with her than it is elsewhere. The *Dreadnought* has bunker capacity for 2,700 tons, but later vessels of the type improve on that. All naval powers do not need ships with enormous provision of this kind. Their vessels seem, therefore, to carry too much weight in guns and armor to leave much for coal.

In respect to armor protection there is little to choose between British and German or Brazilian ships. In speed and in fuel capacity the British ships are superior but have fewer guns. The *Minas Geraes* and her sister ship have twelve 12-inch guns with a turret forward and a turret aft, superimposed above another. The Nassau types have fourteen 11-inch guns in seven barbettes, and cruiser *F* will have twelve guns of the same caliber and the same pattern. The chances are that the fighting efficiency, under war conditions, of the *Dreadnought's* ten guns is higher than that of the *Nassau's* fourteen guns, and the *Dreadnought* has greater speed and better coal capacity. The Vickers and Armstrong companies put 12-inch guns on the Brazilian ships. The United States has preferred the 12-inch, while France thinks more of the 9.4-inch than the 12-inch.

The British ships have been improved with the view of making them capable of operating over wider areas without sacrificing qualities essential to success against vessels of corresponding types designed to operate in narrower areas. The general line of progress is more towards perfection of the different compromises than to the reconstruction of them.

THE LATEST UNITED STATES BATTLESHIPS.

The most recent battleships to be completed for the United States Navy are the *Michigan* and *South Carolina*, of 16,000 tons normal displacement. These ships are 450 feet long on the waterline, with a beam of 80 feet 3 inches and a mean draft of 24 feet 6 inches. The full load displacement is 17,650 tons. The ships are designed for an indicated horsepower of 16,500, to give a speed of 18.5 knots. Twelve Babcock & Wilcox watertube boilers, located in three separate compartments, supply steam at a pressure of 265 pounds per square inch. Propulsion is by means of two outboard turning screws, driven by four-cylinder triple-expansion engines. At full power the engines are designed to turn 125 revolutions per minute. The total machinery weight is 1,600 tons. Nine hundred tons of coal is the normal fuel supply, but the bunkers have a capacity for a maximum of 2,200 tons.

The armament consists of eight 12-inch 45-caliber guns, mounted in pairs in turrets on the center line of the ship—four forward and four aft. The secondary battery consists of twenty-two 3-inch 14-pounder rapid-fire guns, and they are distributed on the main and gun decks. There are also two 3-pounder semi-automatic, eight 1-pounder semi-automatic, four .30-caliber automatic, and two 3-inch field guns. Two 21-inch submerged torpedo tubes bring the total weight of armament up to about 1,150 tons.

The main armor belt is 8 feet wide and 12 inches thick amidships. The main redoubt is 300 feet long, and at the ends there is a light belt of 1½-inch armor. The turrets are protected by 12, 10 and 8-inch armor, the 12-inch armor being distributed on the front of the turrets, the 10-inch on the bar-

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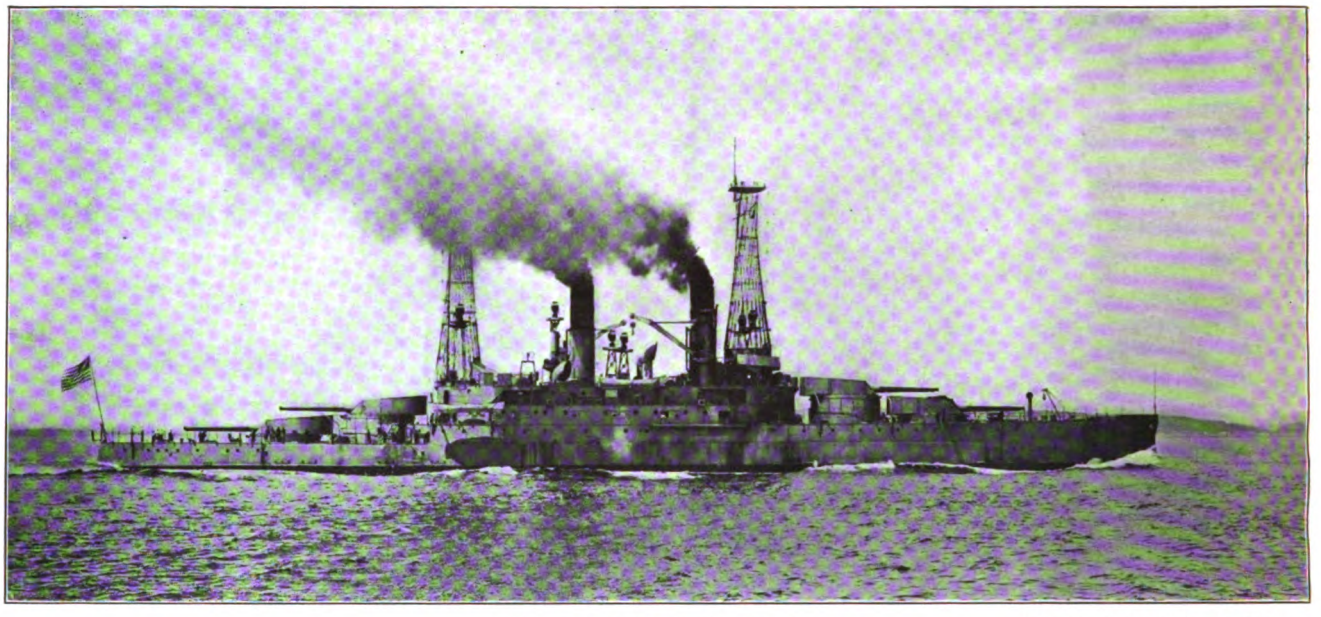
bettes and the 8-inch armor on the sides. The 'thwartship armor bulkheads are 10 inches thick, and the conning tower is protected by 12-inch armor, the total weight of armor being about 4,000 tons.

The *Michigan*, a photograph of which is shown herewith, turret is placed between the two after turrets, as located on the *Florida*, and is sufficiently elevated to permit its guns to fire astern over the aft turret. The main characteristics of modern battleship design are very noticeable in these ships.



UNITED STATES BATTLESHIP MICHIGAN. Photograph by N. L. Stebbins.

was built by the New York Shipbuilding Company, Camden, N. J., and the *South Carolina* by the William Cramp & Sons Ship & Engine Building Company, Philadelphia, Pa.

Four still more powerful ships, the *Delaware, North Dakota, Utah* and *Florida*, of 20,000 tons normal and 22,075 tons full-load displacement, designed for a speed of 21 knots, are fast nearing completion. These ships are armed with ten 12-inch 45-caliber guns, all mounted in pairs in the turrets on the center line of the ship, the secondary battery consisting of fourteen 5-inch rapid-fire guns, together with the usual equipment of small guns. The heaviest armor is 11 inches thick

The *Delaware* and *North Dakota* were authorized in 1906, laid down in December, 1907, and are now over 90 percent complete. The *Utah* and *Florida* were authorized in 1907, and laid down the latter part of 1908, and are now over 30 percent complete. These ships are 518 feet 9 inches long over all, 510 feet long on the waterline. Their beam is 85 feet 3 inches, and the mean draft 27 feet 3 inches. Babcock & Wilcox boilers are used in all of the ships, and provision is made for normal supply of 1,016 tons of coal and a maximum supply of 2,340 tons. The designed horsepower is 25,000, and is to be developed in the *Delaware* by two sets of triple-expansion engines, and in the other ships by Curtis turbines.

Powerful as these last-named vessels are there are now authorized two battleships of 26,000 tons displacement and 21 knots speed, carrying a main battery of twelve 12-inch 50-caliber guns, each capable of throwing an 850-pound shell with a muzzle energy of 50,000-foot tons. The secondary battery is to consist of a large number of 50-caliber 5-inch guns. The main features of the design of these ships will be similar to the *North Dakota* type, but the total horsepower will probably be in the neighborhood of 33,000, and a bunker capacity of 3,000 tons of coal will be required. These ships will be the logical development of the *North Dakota* and *Florida* class, the length being increased to 545 feet, beam to 92 feet, and the draft to 29 feet. The addition of another turret containing a pair of 12-inch guns, of course, alters the general arrangement of the vessel somewhat. This additional

THE OLDEST VESSEL IN COMMISSION.

BY AXEL HOLM.

The distinction of being the oldest vessel in commission in the world undoubtedly falls to the little Danish sloop *Constance*. Although she does not look old or old-fashioned by any means, yet she was built in the year 1723. To-day she is still busy as a tramp between Danish ports, seldom failing to get her cargo of flour or lime, and carry it safely over the same Belts and sounds with which she has been familiar for 185 years.

That this particular age is correct was stated by the Danish Bureau of Shipping only a short time ago. Until recently she figured in the official lists without any age at all, but by looking over the archives very carefully, the Bureau could follow her way through the lists under various names down to the very year in which she was built.

Of course, every stick in the hull has not been kept intact, as, for instance, in 1868, she was given a thorough overhaul, during which her stern was altered and lengthened by about 5 feet, but still the greater part of her hull remains from that old time. Her present owner claims that to-day she is in better sailing condition than when he bought her in 1889, as he has spent some $700 (£144) on a new rig, and other renewals. Anyone, however, who has dealt with old-time products in shipbuilding well knows the excellent kind of oak and other materials commonly used; how gloriously it bears its age, and how hard it is, even for the teeth of time to destroy it.

Even at the great age of 180, this vigorous old ship, in the Great Belt between the islands of Lealland and Finen, rescued and carried safely into harbor a sister of hers in distress. She then got the cargo of the others, as she was in ballast herself, and started off for the port of Malmoe, in Sweden. But here she happened to meet the first serious accident of her long life. She was overtaken by a heavy hurricane, which swept all over Denmark, and on Christmas Day, 1902, she grounded and filled with water near the place of

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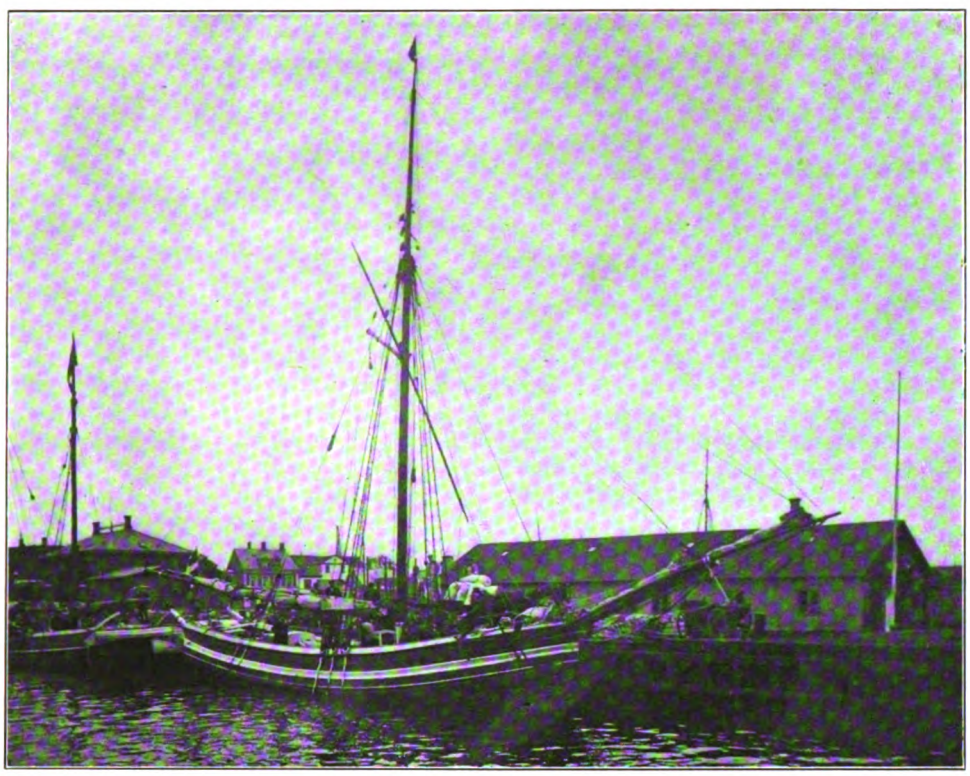
her recent work of rescue. This her owners thought to be her last voyage, but, as a matter of fact, the rough treatment seemed to do her no harm and she is now in service as before.

These facts were told the writer by her present owner and captain, Mr. J. Jeusen, of Lohals, Denmark, to whom she has belonged since 1889. He gave her her present name, and has been nursing and caring for her like a father, his only sorrow being that the old vessel may soon disappear from the lists of the living, as he is an old man and has made up his mind to retire from shipping. As a means to prevent this, however, an attempt is now being made to arouse public interest through Danish newspapers for her preservation as long as possible.



THE DANISH SLOOP CONSTANCE AS SHE APPEARS TO-DAY.

Not very much is known of her earlier history. Until the year 1882, probably under the name *De fire Brödre* (*The Four Brethren*), she belonged to the same family for eighty years, sailed by son after father, and plying between Denmark and Christiania, Norway. From 1882 to 1889 she was owned by Captain C. Böje, of Marstal, Denmark, carrying the name *Catariña* until her present owner obtained her, as previously mentioned.

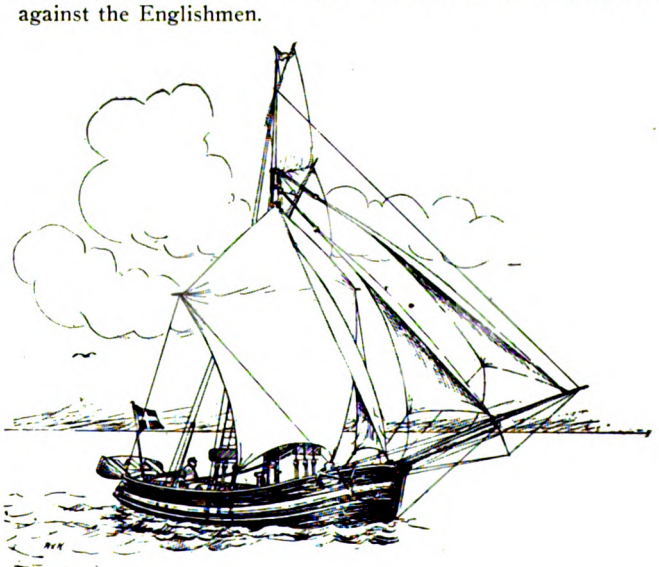
The government's official list of Danish ships describes her as follows:

Name	*Constance.*
Letters	N. B. L. T.
Rigging	Sloop.
Building place	Aerö, Denmark.
Building year	1723.
Material	Oak.
Depth in hold	6.8 feet.
Tonnage, gross	35.
Tonnage, net	27.
Port of registry	Lohals, Denmark.

The length and breadth is given as 52 feet 6 inches, and 14 feet 8 inches, respectively, but it is not definitely known in what manner these measures were taken.

As may be seen from the illustrations, she does not look very great or imposing, but she has proved that her diminutive size is not to be scorned, as in the long course she has beaten many larger craft. If, for instance, we assume that during 150 years the little *Constance* has made fifty voyages a year, carrying about 30 tons of dead weight each voyage, she will, in all, have conveyed more than 200,000 tons of merchandise, and even the giant *Mauretania* will not soon overtake this record.

As a matter of curiosity, it might be mentioned that under the Danish flag there are plying thirty-two sailing vessels built before 1825, and of these, seven were built before 1800. One of them, the schooner *Vigilant*, was built in Baltimore in the year 1790, and has ever since been in service between the Danish Antilles. During the war between Denmark and Britain, 1807-1814, she fought victoriously as a privateer against the Englishmen.



SKETCH SHOWING RIG OF THE CONSTANCE.

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A Century's Progress in Steam Navigation.

Now that steamships of 20,000 tons and over are no longer an uncommon sight, and with steamships of over 40,000 tons displacement driven by engines developing 70,000 horsepower maintaining an average speed of 25½ knots on regular voyages across the Atlantic, it is hard to believe that all this progress is the result of only a hundred years' experience in steam navigation, that, in fact, it is really the outgrowth of much less time than that, since the real development of steam ocean navigation did not begin until 1840. From 1840 to 1860 the development of the ocean-going steamship was steady, but as paddle-wheels were used almost entirely for propulsion, it was on lines somewhat foreign to the recent rapid development. Since 1860 screw propellers have been used exclusively on trans-Atlantic steamships, and therefore it might very well be said that the swift, modern, luxurious trans-Atlantic steamship has been developed within the memory of living man.

The invention of the steamboat cannot be credited to any one man. Robert Fulton was the first to bring out a successful commercial steamboat, but he was by no means the first to experiment with this means of navigation. In America alone, where at that time the facilities for engine building or machine work of any kind were very poor, no less than fourteen actual steamboats had been built and operated previous to the building of the famous *Clermont*. Some of the ideas evolved by Rumsey, Fitch, Morey and Stevens were far in advance of those which Fulton put into practical operation, and which have since become fundamental factors in the development of modern steamships. Their successes are in no way belittled by Fulton's brilliant achievement, no more than are the achievements of such inventors in other countries, as Hulls, Symington, Watt, and others in England.

After the first experimental period in marine engineering, which resulted in the building of Fulton's *Clermont* in America and Bell's *Comet* in England, only a few years elapsed before a steamship made a voyage across the Atlantic ocean. This was accomplished by an American vessel (the *Savannah*) in 1818, although it was not until 1840 that an attempt was made to establish regular communication by steamship between England and America, when the *Britannia*, of the newly-organized Cunard line, made her first voyage to America. The *Britannia* was only a small, wooden paddle steamer of 1154 tons and 740 indicated horsepower, capable of an average speed of 8½ knots. She was only 207 feet long, 34 feet 4 inches broad, and 24 feet 4 inches deep, but she marked the beginning of what has since become the field of greatest activity and development in marine engineering and naval architecture, the trans-Atlantic steamship. The culmination of this development in the modern turbine-driven greyhound, capable of crossing the Atlantic at an average speed of 25½ knots, is a fitting climax to a century's progress in the development of steam navigation.

During this comparatively brief progress (in reality little more than half a century), the length of steamships has been quadrupled, both the breadth and depth have increased by about 115 percent, the tonnage is nearly 30 times greater to-day than it was then, and the engine power 95 times greater. This increase in dimensions, however, gives but a small idea of all that has been accomplished by the marine engineer and naval architect during this time. Great as has been the development in size, power, speed and luxuriousness of the modern liner, no less remarkable have been the economies effected in the weight of marine engines as compared to their power as well as in their

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coal consumption. In the *Britannia* of 1840, the main propelling machinery developed only from 1½ to 2 horsepower per ton weight, and the coal consumption was from 4½ to 5 pounds of coal per indicated horsepower per hour. With the reciprocating marine engines of the present day at least 6 horsepower can be developed per ton weight, and the coal consumption averages only from 1½ to 2 pounds per indicated horsepower per hour. With turbine-driven merchant ships from 12 to 14 horsepower per ton of propelling machinery can be obtained, while for naval vessels still greater economy is obtained. On large battleships about 12 horsepower per ton of machinery can be obtained with reciprocating engines, and about 14 with turbines; on fast cruisers the figures are in the neighborhood of 19 for reciprocating engines and 25 for turbines, while on the modern torpedo-boat destroyer about 45 indicated horsepower can be obtained per ton of machinery with reciprocating engines, and about 65 horsepower per ton weight with turbines. These marvelous results are obtained without any increase of coal consumption; in fact, better economy in this respect is being attained daily. Undoubtedly even better results than these can be obtained in the near future if the problem of reversing steam turbines is simplified, or if more efficient forms of high-speed propellers are devised. This great increase of power per ton weight of machinery is the vital point of all progress in marine engineering and is the particular contribution of marine engineers toward economy in size and cost.

As regards the construction of ships' hulls, there is nothing to-day to limit the size of the vessels commercial considerations demand. Naval architects are now able to design and build vessels of any dimensions which are found necessary to carry on commerce most economically and to suit any harbor conditions which exist. This is made possible primarily by the substitution of steel for iron and wood construction. In the old days of wooden ships the size of ships was limited, because beyond a certain length the structure of vessels was inadequate to withstand the stresses occasioned by the weight of the ships themselves and their cargo. Hogging occurred in many of the larger wooden ships, and this could not seem to be prevented by any form of construction adaptable with wood as the material. The substitution, first of iron and later of steel, for wood has enabled great economy to be effected in the weight of ships' structures. Formerly this structural weight represented perhaps fifty per cent of the total weight of a full loaded vessel. If wood had remained the chief shipbuilding material it would have been absolutely impossible to approach the dimensions or speeds which have now been attained. With the steel which is now procurable for shipbuilding material and with the forms of construction which are used, notwithstanding the enormous increase in length, tonnage, and total weight of modern steamships, the proportion of that total weight devoted to the hull structure itself is very much less than it was in the old days of smaller wooden vessels.

To what extent and with what rapidity recent progress in marine engineering has outstripped all previous development is evident when it is considered that at the time the giant turbine-driven Cunard steamships Lusitania and Mauretania were projected the most powerful turbines which had then been tried were those fitted in the third-class cruiser Amethyst, an installation which aggregated only about 12,000 horsepower, or about 4,000 horsepower for each unit. The advance from these turbines to the four turbines of the Lusitania and Mauretania, each capable of developing nearly 18,000 horsepower, or a total of about 70,000, was a step which corresponded practically with the entire development of reciprocating engines from 1860 down to the present day.

Although in the early development of steam navigation most innovations were made in the merchant marine and afterwards copied in naval vessels, yet the same does not hold true to-day. Iron was generally introduced as a shipbuilding material for merchant vessels as early as 1832, but it was not until about 1860 that it was generally adopted for naval vessels. Previous to 1854 all naval vessels were wood-built, unarmored vessels.

The screw propeller, on the other hand, was introduced into both merchant and naval vessels at about the same time in the early forties. Compound engines were not introduced in the British navy until 1871, whereas they had been in use in merchant vessels some years before that. Twin screws were first used in the *City of Paris* and the *City of New York*, of the Inman line in 1889. From 1835 to 1845 vertical cross-head engines, side-lever engines, beam engines and oscillating engines were all introduced in merchant ships and became generally used. The type of engine used in early war vessels was usually either the side-lever, heavy long-stroke engine, such as was used in the *Phoenix* in 1830, and which was popular in the mercantile marine as late as 1860, when paddle-wheels were generally discarded in favor of screw propellers, or the trunk type of engine, which was exceedingly low and compact, having horizontal cylinders and return connecting rods.

What the future has in store in the way of developments in ships and propelling machinery is impossible to predict. At present ships 890 feet long, 92 feet beam, with a molded depth of 64 feet and a displacement of 60,000 tons are under construction; but in point of engine power and speed they do not equal the *Lusitania* or *Mauretania*, although it is very probable that they will show many improvements in economy over these vessels. In the light of recent progress, however, the future promises brilliant achievements.

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Progress of Naval Vessels.

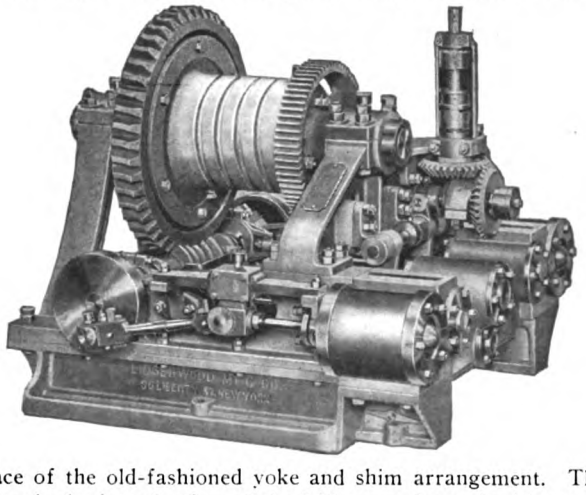
The Bureau of Construction and Repair, Navy Department, reports the following percentages of completion of vessels for the United States navy:

	Tons.	Knots.		July 1.	Aug. 1.
BATTLESHIPS.					
S. Carolina..	16,000	18½	Wm. Cramp & Sons.....	94.6	96.5
Michigan ...	16,000	18½	New York Shipbuilding Co...	98.3	99.4
Delaware ...	20,000	21	Newp't News Shipbuilding Co.	86.9	91.8
North Dakota	20,000	21	Fore River Shipbuilding Co..	87.7	90.3
Florida	20,000	20¾	Navy Yard, New York.....	19.9	24.8
Utah	20,000	20¾	New York Shipbuilding Co..	26.8	33.2
TORPEDO-BOAT DESTROYERS.					
Smith	700	28	Wm. Cramp & Sons.....	94.6	95.6
Lamson	700	28	Wm. Cramp & Sons.....	84.9	88.4
Preston	700	28	New York Shipbuilding Co...	82.2	90.1
Flusser	700	28	Bath Iron Works.....	83.6	90.0
Reid	700	28	Bath Iron Works.....	79.8	84.2
Paulding ...	742	29½	Bath Iron Works.....	17.6	21.7
Drayton	742	29½	Bath Iron Works.....	17.6	20.7
Roe	742	29½	Newp't New Shipbuilding Co.	51.6	57.4
Terry	742	29½	Newp't News Shipbuilding Co.	47.6	51.9
Perkins	742	29½	Fore River Shipbuilding Co..	37.9	44.6
Sterrett	742	29½	Fore River Shipbuilding Co..	35.8	41.2
McCall	742	29½	New York Shipbuilding Co..	17.1	22.5
Burrows	742	29½	New York Shipbuilding Co..	16.7	22.4
Warrington..	742	29½	Wm. Cramp & Sons.....	23.9	32.7
Mayrant	742	29½	Wm. Cramp & Sons.....	30.0	37.2
No. 33.....	...	....	Bath Iron Works.....	0.0	1.1
No. 35.....	...	....	Fore River Shipbuilding Co..	0.0	0.8
SUBMARINE TORPEDO BOATS.					
Stingray	...	..	Fore River Shipbuilding Co..	94.3	95.0
Tarpon	...	..	Fore River Shipbuilding Co..	94.3	95.0
Bonita	...	..	Fore River Shipbuilding Co..	87.3	90.6
Snapper	...	..	Fore River Shipbuilding Co..	87.1	87.6
Narwhal ...	...	..	Fore River Shipbuilding Co..	93.7	94.5
Grayling ...	...	..	Fore River Shipbuilding Co..	90.1	90.6
Salmon	...	..	Fore River Shipbuilding Co..	81.1	81.8
Seal	...	..	Newp't News Shipbuilding Co.	20.4	23.2
Pickerel			The Moran Co.....	3.1	4.3
Skate			The Moran Co.....	3.2	4.3

ENGINEERING SPECIALTIES.

New Lidgerwood Steering Engine.

The Lidgerwood Manufacturing Company, of New York, having recently established a marine department, is now building a line of steering engines of approved design, one type of which is shown herewith. This engine is not a radical departure in design from those now in general use. It does, however, contain a number of important features which will be appreciated by practical men. Two of these features are clearly shown in the illustration. The first is the introduction of the Lidgerwood standard gib and key connecting rod in



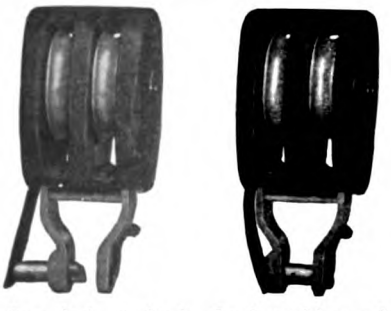
place of the old-fashioned yoke and shim arrangement. The other is the introduction of the Lidgerwood standard locomotive type of cross-head and guide instead of the old-style plug cross-head and barrel guide. The application of these features is not new for ship work, as they have been extensively used on ships' winches for a number of years by many steamship lines of this and other countries.

The arrangement of the engine is such as to permit of the easy adjustment for wear, thereby obviating the disagreeable noise which frequently arises from steering engines after they have been in use for a short while. Great care has been taken in designing the machine so as to obtain the maximum strength of parts where it is most needed. The engine is exceedingly compact, and is arranged for easy inspection and adjustment.

The machine is built from new patterns, in which all the improvements suggested by an extended experience and observation have been embodied. The engine illustrated is an automatic steam-type of steering engine, although the company also builds a combined hand and steam type and also a screw-gear engine for large ships. All of these engines are built on the same general lines and under the Lidgerwood system of duplicate parts, which not only insures accuracy but at the same time makes it possible at any time to promptly procure repair parts which can be put into place at once without requiring any work in fitting.

Wick's Patent Releasing Device for Lifeboats.

A new releasing device for lifeboats has recently been placed on the market by David Kahnweiler's Sons, New York, which is both simple and efficient. The main feature of the device consists of a sliding bolt attached to a spring, which tends to draw the bolt out and release the boat. The bolt is held in place when in operation by the weight of the boat, and is secured by a thumb catch, which serves the same purpose as the mousing of a hook and prevents the automatic device from



operating before it is desired. In launching a boat, just as soon as the weight of the boat is on the sliding bolt the thumb catch can be removed, in which case the bolt remains in position until the boat is water-borne, when it automatically springs out of the way, releasing the boat immediately. If it is desired, the thumb catch need not be removed until the boat is water-borne. The method of operation is so obvious that it requires no experience to use the device. Therefore, it is very unlikely that any mishap could occur with it. Because there are so few parts to the device the block is brought closer to the boat than if fastened in any other way. This allows more distance between the upper and lower blocks for hoisting, so that the davits need not be so high in order to give the requisite clearance. The blocks are made of galvanized iron or lignum vitæ sheaves with bronze rolls.

A Remarkable Coaling Device.

Some remarkable records in handling coal on board ship are being made on the United States collier *Mars*. By means of a new device, which is the invention of Spencer Miller, chief engineer of the cableway department of the Lidgerwood Manufacturing Company, New York, two men are able to discharge 117 tons of coal per hour from a single hatch of the collier. Twenty men, manning as many hatches of this new collier, can discharge a thousand tons of coal per hour and over. The entire cargo of the collier can be emptied in about eight hours. This new device, which is called the marine transfer, consists of a clam-shell bucket, which digs the coal from the hold, hoists it, swings it outboard and dumps it onto the deck of a warship, where it is distributed by the ship's crew into the bunkers.

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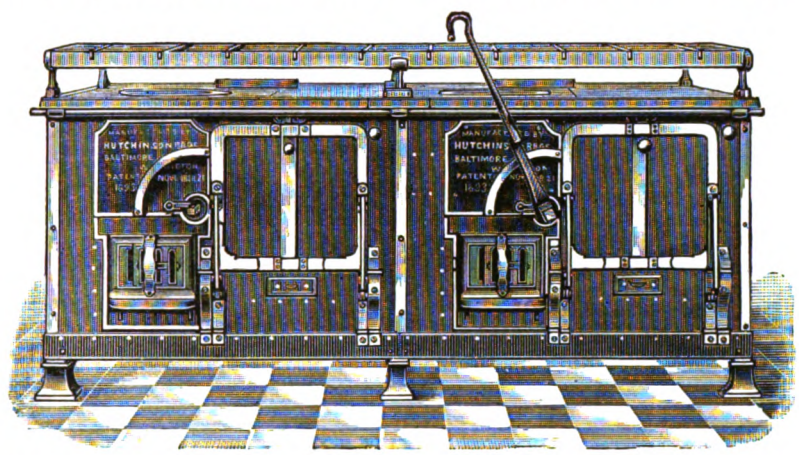
In contrast to such a remarkable performance the present method of handling coal in vogue in all navies seems slow and cumbersome. According to the present method, sailors are sent into the hold of the collier, where they shovel the coal into bags. The ship's winches and derricks hoist the bags and deposit them on the deck of the warship, where they are distributed to the bunkers by the crew. By this method 25 tons of coal per hour per hatch is an average performance and 40 tons is the maximum. This, in fact. can only be accomplished by the aid of about forty men. The advance from handling 40 tons of coal per hour by forty men to 117 tons per hour by two men is indeed a remarkable performance.

Hutchinson's Steel Plate Marine Ranges.

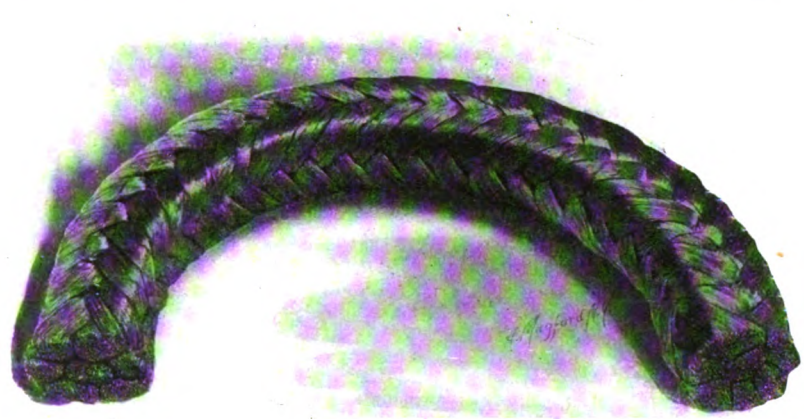
The body of the Hutchinson steel plate marine range, manufactured by Hutchinson Bros., Baltimore, Md., is made of heavy cold-rolled steel strongly riveted and bolted at the joints. All trimmings and braces are made of wrought and malleable iron, highly polished and nickel-plated if desired. The castings, such as the top, grate, fire-plates and water-back, are made of fine quality pig iron. A special feature of the range is the oven bottom, which is made of boiler plate, reinforced with angle-iron, a construction which, it is claimed, is non-warpable. The range is fitted with the Hutchinson patent shaking and dumping grate, suited for burning either hard or soft coal. The grate is so constructed that the fire can be shaken, kept bright and dumped without removing the covers or opening any doors. It is also claimed to be very durable. The range shown in the illustration, which is supplied with guard rails, cross bars, feet and steel flues, also with side braces and rods to bolt to the floor, is 7 feet 6 inches long and 39 inches deep, with two fires and two ovens, each oven being 28 by 18 by 16 inches.



Duval Metallic Packing.

Radical changes have been made in power plant machinery in the last decade; high-pressure steam has almost entirely replaced low-pressure service; superheated steam is being generally used; the internal-combustion engine has proved practical; enormous hydraulic pressures are now carried. All of these improvements have demanded the most exacting performance of packing, and, as the soft compositions of the old days could not meet the new requirements, many different kinds of packing have been placed on the market for this purpose. One of the first of these was the Duval woven wire metallic packing, which is manufactured by the Power Specialty Company, New York.

Duval metallic packing is made of a fine, white alloy wire, accurately plaited in square form. This wire is of special composition, determined after extensive experiments and calculated to obtain a maximum strength and elasticity with a minimum friction and wear. It is claimed that it will resist enormous pressures and maintain a tight joint without bearing unduly against the rod, while, at the same time, it is of such hardness that it will not cut the rod or wear unevenly, although if applied to a rod already scored it will adjust itself to the uneven surface. It is also claimed that its heat-resisting properties are such that it cannot burn when submitted to the highest temperatures, and that it does not deteriorate when kept in stock. Its field of service is practically unlimited, for it is designed to maintain a tight joint against any water pressure up to 5,000 pounds per square inch, and also against any temperature up to 900 degrees F. The speed of the rod or plunger has little effect on the packing, as it may be used on rods moving as fast as 1,750 feet per minute or upon slow-speed plungers. It is not recommended for use on brass rods.



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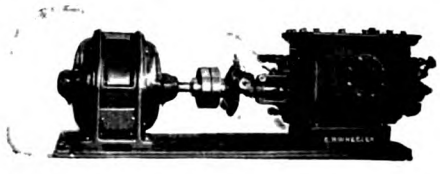
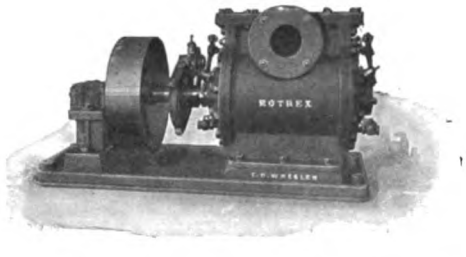
An Improved Type of Marine Air Pump.

It is always of first importance to economize on the space occupied by machinery in a steamship. One of the largest auxiliaries which is used is the old-style air pump, which, on account of having large cylinders and operating at slow speeds, takes up an undue amount of space. This is true whether the air pump is of the independently steam-driven beam type or direct connected. A very much smaller pump, known as the Rotrex (Pratt's patent), has just been put on the market by the C. H. Wheeler Manufacturing Company, Philadelphia, Pa., in order to take the place of the old-style large and bulky pump. The Rotrex pump embodies all the essential features of a high-grade, high-vacuum air pump, and is adapted for



direct connection to other auxiliary machinery. The construction of the pump is very simple, consisting of a light-weight cylindrical casing and one rotor, eccentrically mounted on a heavy steel shaft carried in outboard ring-oiled bearings independent of the stuffing-boxes. Division between the suction and discharge in the pump cylinder is made by means of a radius cam, which is carried in independent bearings, and is operated by means of a lever and crank from the rotor shaft on the outside of the pump. These three parts, namely, the rotor, radius cam and driving crank, are the only moving parts in the pump. By this arrangement it is claimed that internal contact, which has hitherto been the cause of the failure of many rotary pumps, is entirely eliminated, the rotor operating with a close clearance from the bore of the pump cylinder and



the cam maintaining a close clearance from the rotor. By an ingenious arrangement of ports these clearances are thoroughly water sealed at all times, insuring a high vacuum. No suction valves are used, and the discharge valves are of the high-speed metallic type, to eliminate expensive up-keep. The pumps are built in capacities from 50 to 5,000 horsepower in one unit, and beyond that size multiple units are used, an independent air-pump engine being provided with one Rotrex pump, driven from each end of the crank shaft and direct connected to the engine. The usual marine arrangement consists of a centrifugal circulating pump driven by a vertical high-class economical steam engine with the Rotrex air pump direct connected. By this arrangement one engine drives both pumps, the speed of the combined outfit being 180 to 250 revolutions per minute, depending upon the size of the unit. This arrangement eliminates the additional steam cylinders ordinarily used to drive an air pump. It is claimed that the Rotrex pump produces the highest possible vacuum which is needed with the latest developments in steam turbines. This is accomplished with a machine of small size, which is impossible with the old-style reciprocating pump.

TECHNICAL PUBLICATIONS.

Compressed Air Work in Diving. By G. W. M. Boycott Size, 6 by 9½ inches. Pages, 116. Figures, 16. London, 1909: Crosby, Lockwood & Sons. Price, $4.00.

This book is intended as a practical hand-book embodying the main principles of compressed air work and diving. Chapters 1 and 2 give a set of rules for stage decompression which will undoubtedly be found exceedingly useful by anyone engaged in this line of work. The method outlined was originated as the result of the work of a committee appointed four years ago by the British Admiralty to report upon the conditions of deep-water diving, and it was also based upon recent investigations of Drs. Haldane and Boycott and Lieut. Damant at the Lister Institute of Preventive Medicine. The subject of diving is included in the first four chapters, the remainder of the book being given over to the use of pneumatic caissons and cylinders, tunneling, etc. In discussing the subject of tunneling, the methods used in constructing the Blackwall, the Rotherhithe and Hudson River and East River tunnels are discussed.

The Screw Propeller. By A. E. Seaton. Size, 6½ by 9 inches. Pages, 255. Plates, 6. Figures, 65. London, 1909: Charles Griffin & Company, Ltd.; Philadelphia, J. B. Lippincott Company.

In the preface the author states that the object of this book is to amplify and explain the subject matter relating to propellers which was given in his *Manual of Marine Engineering* published thirty-two years ago. In that work only general rules and formulæ sufficient to satisfy the wants of designers were given, whereas in the present volume all that is new and of importance regarding the screw propeller, paddle-wheels, hydraulic propulsion, etc., together with much that is of interest, although comparatively old, is taken up. No attempt has been made to include abstruse and highly mathematical investigations concerning the theory of the resistance of ships and propellers, the book being intended more particularly for students, draftsmen, sea-going engineers, designers and the like, who have immediate use for necessary rules and data for the best design of propellers. The subject of the screw propeller itself is not reached until approximately the middle of the book, the first chapters being taken up with the history of early and modern marine propellers arranged in chronological order. This is followed by short chapters on the resistance of ships, slip, cavitation and racing, and then the subject of paddle-wheels is taken up. This is treated with perhaps more thoroughness than is usual in books on marine propulsion, much valuable data being given. A short chapter describes what has been done in the way of developing hydraulic propulsion, and points out the theoretical advantages and disadvantages of this means of propulsion. Coming to the screw propeller itself, we find the subject treated with the author's characteristic thoroughness and clarity. The geometry of the screw propeller, various forms and types of propellers and the materials used in their construction, besides the theory of the screw propeller, are all discussed at length. The last part of the book includes data from the most recent experiments made by Sell, Isherwood and others. Some valuable tables are also included, giving complete data regarding the performance of various steamships on trials.

Steam Power Plant Piping Systems. By William L. Morris, M. E. Size, 6 by 9 inches. Pages, 490. Figures, 389. New York, 1909: McGraw-Hill Company. Price, $5.00 net.

The subject matter of this book is the result of the author's personal experience in the design of piping systems for steam power plants, and the subject is discussed solely from his point of view. This does not mean, however, that the book lacks breadth or completeness, for the author has had a wide and varied experience and is amply qualified to write as an expert

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on his subject. In fact, the results of the study and work of a specialist are here presented in such form that the average engineer can profit by them. The design of boilers and engines is not touched upon, but all auxiliary apparatus in the pipe circuit between the boiler and engine and in the various piping systems for steam, oil, air, etc., have been treated and their general design discussed.

The author points out that the chief requisite in pipe work engineering is to so design as to permit repairs of disabled lines without interfering with the regular service of the plant. This he suggests can best be accomplished by allowing the pipe fitters and manufacturers to design the details of the piping, a part of the work which the engineer himself is seldom capable of doing to the best advantage and for which he can rarely afford to employ specialists. It would then devolve upon the piping contractor to design the details, and the responsibility for good pipe design would then be fixed, for the contractor's reputation would depend upon his design as well as upon his workmanship. The engineer could then devote his entire time to getting out complete piping system diagrams, and so designing the complete arrangement as to meet the chief requisite for good pipe work mentioned above, work which he is or should be qualified to do. This method deserves thorough consideration, for it evidently has much to recommend it.

Marine Engineering. By A. N. Somerscales. Size, 5½ by 8½ inches. Pages, 445. Figures, 153. Glasgow, 1909: James Munro & Company, Ltd.; London, Simpkin, Marshall, Hamilton, Kent Company, Ltd. Price, 12/6 net.

The author of this book has had considerable experience in assisting candidates to prepare for the Board of Trade examination for extra first-class engineers, and the information needed for such work forms the basis of the book. While the book is primarily useful for those who desire a hand-book for preparation for the extra examination, yet it covers most of the ground usually included in mechanical and marine engineering, and so forms a valuable book on the general subject of engineering. It is divided into three parts, with an appendix. Part I. contains short essays on physical and engineering subjects; Part II., solutions of questions on mensuration, mechanics, etc.; Part III., the proof of rules and formulæ used in engineering work, while the appendix contains tables and examination papers. While the book is by no means an elementary treatise on the subject, yet it is no more theoretical or complicated than the subject demands. In fact, much of the material is presented in the form of practical questions and answers, the complete solution of the problem being given in detail in each case.

History of New York Shipyards. By John H. Morrison. Size, 6 by 9 inches. Pages, 165. Figures, 22. New York, 1909: William F. Sametz & Company, Price, $2.00.

During the era when wooden sailing ships formed the principal part of the mercantile marine in every country, America had an undoubted supremacy, due to the excellence of her ships and sailors. At this time wooden shipbuilding was in its most prosperous condition, and New York shipyards were turning out some of the fastest and most famous ships afloat. With the advent of iron and steel ships shipbuilding in and about New York rapidly declined, and, although numerous large and important repair yards have been developed to meet the necessities of such a large port, yet shipbuilding, as applied to the construction of new vessels, has never reached the same importance in New York that it formerly occupied in the days of wooden sailing vessels. The story of the development and decline of this industry involves much that is of interest, not only regarding mechanical details and methods of construction, but also regarding labor conditions and the men who carried on these enterprises. These are carefully treated by the author.

One of the most interesting parts of the book is that dealing with clipper ships, in which the records of some of the most prominent clipper ships that sailed from New York from 1841 to 1860 are given. This information has evidently been compiled with the greatest care and accuracy, and it is the only thing of the kind which we have ever seen.

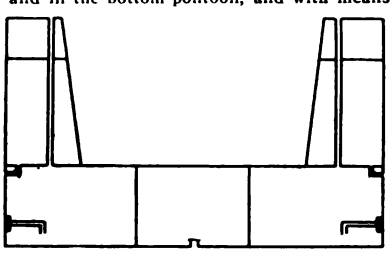
SELECTED MARINE PATENTS.

The publication in this column of a patent specification does not necessarily imply editorial commendation.

American patents compiled by Delbert H. Decker, Esq., registered patent attorney, Loan & Trust Building, Washington, D. C.

916,736. PNEUMATIC FLOATING DOCK. JOSEF LÖFFELHOLZ, OF STERKRADE, GERMANY, ASSIGNOR TO GUTEHOFFNUNGSHÜTTE, AKTIENVEREIN FÜR BERGBAU UND HÜTTENBETRIEB, OF OBERHAUSEN, II, GERMANY.

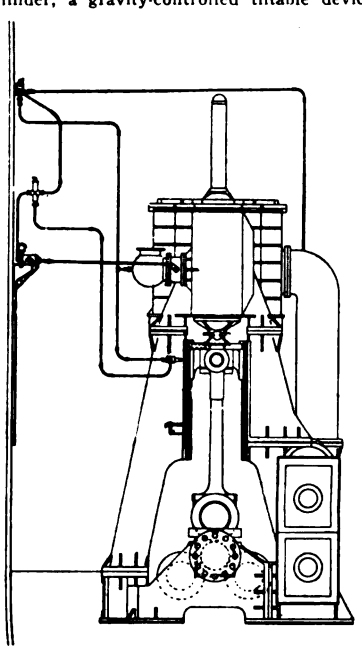
Claim.—A floating dock with independent air compression chambers in the side walls, and in the bottom pontoon, and with means for admitting



water directly into said chambers from the outside to compress the air therein, said chambers having no communication with each other. One claim.

919,718. GOVERNOR FOR MARINE ENGINES. JOHN GORDON, THOMAS JACKSON, AND CHARLES ANDREWS, OF LONDON, ASSIGNORS TO ANDREW'S GOVERNOR PATENTS LIMITED, OF LONDON, A COMPANY OF GREAT BRITAIN AND IRELAND.

Claim 2.—In a speed-governing apparatus for marine engines, a means for controlling the supply of power to the engine, a cylinder for operating said means, a valve for controlling the passage of motive fluid to said cylinder, a gravity-controlled tiltable device, arranged to



operate said valve, in combination with a momentum governor, and an automatic by-pass valve arranged to admit motive fluid to said cylinder and to cut out from action the valve first named and means operated by the said momentum governor for supplying motive fluid to the by-pass valve to operate the latter. Two claims.

920,285. FLOATING DRYDOCK. WILLIAM THOMAS DONNELLY, OF BROOKLYN, N. Y.

Claim 5.—In a floating drydock, sides, pontoons, compartments in said pontoons each compartment provided with a water inlet and a water outlet, a pump having a combined inlet and outlet into and from the compartment and a combined water inlet and outlet communicating with the water inlet and the water outlet of the compartment and means for preventing water from being discharged from the water inlet of the compartment. Six claims.

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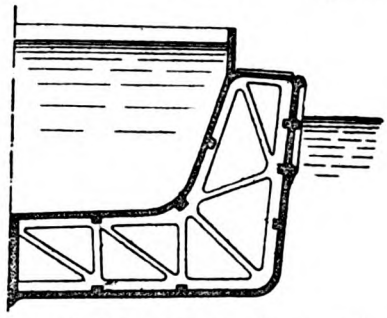
920,046. FLOAT OF REINFORCED CONCRETE. CARLO GABELLINI, OF ROME, ITALY, ASSIGNOR TO SOCIETA' CEMENTO ARMATO E RETINATO GABELLINI, OF ROME, ITALY.

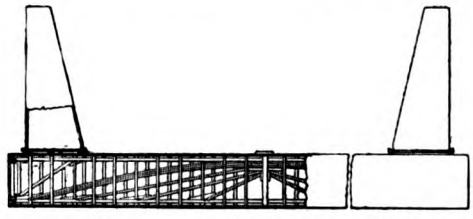
Claim 1.—Floats formed of reinforced concrete provided with hollow



watertight compartments, allowing passage of a person through said compartments. Two claims.

920,282. FLOATING DRYDOCK. WILLIAM THOMAS DONNELLY, OF BROOKLYN, N. Y.

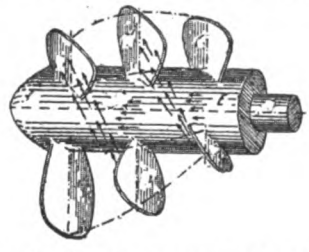
Claim 1.—In a floating drydock, a series of pontoons buoyant when filled with water, sides or wings supported thereon non-buoyant when



filled with water and passages establishing communication between said pontoons and sides or wings, whereby water is admitted to and exhausted from the sides or wings through the pontoons. Three claims.

921,423. SCREW-PROPELLER. GEORGE MACKANESS, OF DRUMMOYNE, SYDNEY, NEW SOUTH WALES, AUSTRALIA, ASSIGNOR OF ONE-HALF TO JOHN BARNES, OF MOSMAN, SYDNEY, ANSTRALIA.

Claim 1.—A propeller comprising an elongated hub, a plurality of series of blades, each series having its blades increasing in length and similarly proportioned up to the limit of their respective length, and



said blades in each of said series arranged aslant the hub in a direction opposite the pitch of the blades and overlapping when viewed in a direction parallel to the axis of the hub. Two claims.

921,641. METHOD OF PREVENTING CORROSION OF METALS IMMERSED IN LIQUIDS. PEREGRINE ELLIOTT GLOUCESTER CUMBERLAND, OF ST. KILDA, VICTORIA, AUSTRALIA.

Claim.—The method of preventing the corrosion and decomposition of propeller shafts and other metallic portions of ships immersed or in contact with sea water and whereby two or more electrically opposed metals are in juxtaposition and connected in parallel and constitute a negative electrode, consisting in placing additional iron means in contact with the water in proximity to the metal parts to be protected and insulating said iron means from said parts except through the sea water, and connecting said metal means in parallel and to the positive pole of an auxiliary source of electrical energy having a higher electromotive force than that caused by the difference of electric potential between the various metals comprised in the structure to be protected, and connecting the negative pole to said source of energy and said metals to be protected constituting the negative electrode. One claim.

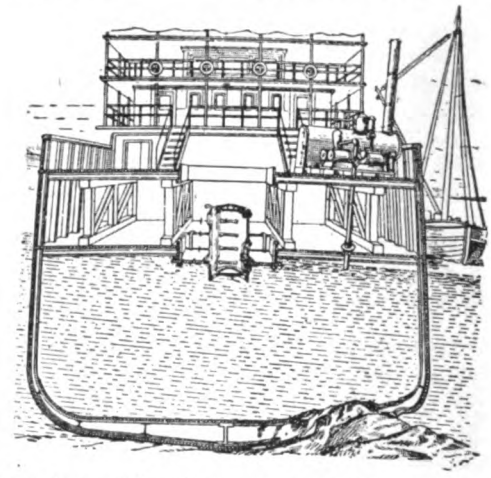
British patents compiled by G. F. Redfern & Company, chartered patent agents and engineers, 4 South street, Finsbury, E. C., and 21 Southampton building, W. C., London.

24,085. TURBINES. H. DAVEY AND H. N. DAVEY, EWELL, SURREY.

Turbines are driven by a mixture of hot air and steam, or by a mixture of combustion products and steam. In one modification, the two fluids do not mix until exhausted from the turbine. Combustion products pass from a combustion chamber upwards through a heater, thereby heating air drawn in by a fan. The combustion products then raise steam in a generator, which passes along a pipe to a turbine wheel, after which it mixes with the hot air passing through the heater. This mixture drives a turbine wheel and exhausts into the combustion chamber thereby furnishing the required oxygen. In a modification, the combustion chamber is surrounded by a generator. The lower part of a turbine wheel is driven by the combustion products, and the upper part by steam from the generator. The flow of steam is controlled by a valve. The mixture exhausts into a condenser, the condensed steam being removed by a suitable pump, and the residual gas being withdrawn by a fan. In a further modification the combustion products, on leaving the combustion chamber, raise steam in a generator. The steam acts upon a turbine wheel and then, mixed with the combustion products, acts upon a turbine. The mixture next passes through a condenser, whence the residual gas is withdrawn by a fan.

24,482. RAISING SUNKEN VESSELS. W. W. WOTHERSPOON AND R. O. KING, NEW YORK, U. S. A.

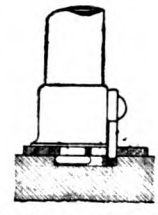
Relates to the method of raising stranded or sunken vessels, in which the ordinary means of communication with the various compartments are made air tight, the decks and walls of the compartments are braced and strengthened to withstand the pressure, airlocks are provided for the ingress and egress of workmen, and compressed air is admitted to expel the water from the compartments. According to the present invention, when the leak is in the side of a compartment, the water is expelled to the top of the hole by the air pressure, and the hole is closed by the progressive downward application of a covering. When



leaks occur in a number of compartments, means are provided for adjusting the air-pressure according to the different hydrostatic pressures encountered, and, in making the hatchways air tight, the hatch cover and gasket are temporarily held against the coaming until the compressed air is admitted. The deck is strengthened by beams or braces or by other means. To render the compartment air tight, a plate or covering is held against the coaming of the hatchway with a rubber gasket packing is interposed. The plate is temporarily held in place before the admission of compressed air by means of vertical stay-bolts. To the coaming of the hatchway is applied an air lock with doors for the entry and exit of workmen. The air is admitted by a pipe from the compressor placed in any suitable position. To adjust the air pressure according to the hydraulic pressure encountered, the air pipes may be provided with reducing valves.

24,901. SHIP'S STANCHIONS. HOSKINS & SEWELL. MIDLAND BRASS WORKS, BORDESLEY, AND C. JOHNSON, BIRMINGHAM.

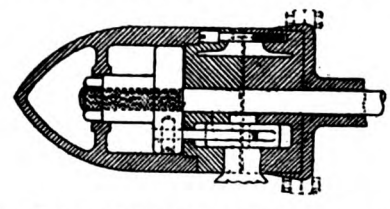
The lower end of the stanchion is provided with a headed stud engaging a keyhole-shaped slot in the base plate. The larger end of the slot is of such a size as to admit the head of the stud. To prevent inadvertent detachment and to keep the stanchion end in place, a loosely



pivoted catch is carried by the stanchion, the lower end of which engages the end of the slot. Clearances are provided to enable the catch to swing clear. Instead of being pivoted, the catch may consist of a loose ring surrounding and sliding upon the stanchion. A downwardly projecting peg is provided to fit the end of the slot.

653. SCREW-PROPELLERS. G. F. VILLINGER, LONDON.

The boss of a reversible propeller is constructed in two main portions and is provided with a covering or cap. The blades have shanks with collars, and an inner journal mounted in bearings formed in the halves of the boss, which is screwed into or bolted to an enlargement on the



propeller shaft. The reversing mechanism comprises a sliding cylindrical block placed in the after part of the propeller on the end of the reversing rod and connected by links to the collars of the blades. Instead of the rods racks engaging with teeth on the collars may be used.

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